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Influence of Additives on Compressive Strength of Roller Compacted Concrete

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ABSTRACT
The roller compacted concrete pavement is considered a heavy duty and sustainable pavement, the verification of its compressive strength is essential in the design. In the present assessment, three types of additives namely (fumed silica, hydrated lime, and fly ash) are implemented for partial replacement of Portland cement for preparation of roller compacted concrete mixtures. Dense and gap aggregate gradation have been implemented for the preparation of roller compacted concrete slab sample. The roller compacted concrete have been prepared at optimum cement requirement and at (2 and 4) % cement below and above the optimum. Cube specimens were extracted from the slab samples using diamond saw. The cube specimens were subjected to the ultrasonic pulse velocity determination then were tested for compressive strength using two testing positions, parallel and perpendicular to the rolling direction. Dense graded mixture exhibits higher compressive strength by (14.5, 2.2, and 1.8) % than gap graded mixture at (10, 12, and 16) % cement content respectively. The parallel testing position of the cube specimens exhibit higher compressive strength for gap graded mixture than that of dense graded mixtures. Dense graded mixture permits higher ultrasonic pulse velocity traversing perpendicular to the rolling direction than gap graded mixture. The compressive strength increases by (229, 103, and 32.3) % and (201, 76.4, and 36.4) % at (10, 12, and 15) % lime replacements of cement for dense and gap gradations respectively. The compressive strength increases by (267, 61.7, and 26.4) % at (20, 30, and 40) % replacement of cement by fly ash for gap gradations respectively.

Keywords: Compressive Strength, Roller Compacted Concrete, Additives, Gradation, Fumed Silica, Lime

1. INTRODUCTION
Roller-compacted concrete pavement mixture exhibits zero-slump and presents a higher compressive strength than traditional concrete, when the same cement content is implemented. This can be due to the high level of aggregates interlock which is achieved by roller compaction. Ashrafian et al., [1] revealed that the compressive strength is the key characteristic of the roller compacted concrete pavement, it exhibits significant impact on the cost of production. Vahedifard et al., [2] evaluated the effects of using silica fume and

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pumice which are considered as supplementary cementitious materials on the workability and compressive strength of low-cement content roller compacted concrete mixtures. Different roller compacted concrete mixtures were prepared with four types of binder and two binder contents. Compressive strength test was conducted. Test results indicated that the incorporation of 10% of silica fumes has increased the compressive strength of the mixtures. However, the workability has significantly decreased of fresh mixtures. The pumice additive has made the specimens more workable but had a negative impact on the compressive strength. Lam et al., [3] investigated the effects of fly ash on compressive strength and durability properties of roller-compacted concrete mixture. The cement was replaced by fly ash at two ratios of (20, and 40) %. The mixture proportions design was determined by soil compaction method. The compressive strength of the mixture was examined after (3, 7, 28, and 91) days age. The results revealed that using of fly ash as cement substitute has improved the compressive strength at long-term age. A replacement of cement by 20% of fly ash had provided the requirements of durability and strength requirements for the pavement. Ashteyat et al., [4] stated that increasing white cement bypass dust replacement ratio to more than 10% can result in degrading the mechanical properties (compressive strength, splitting tensile strength and modulus of elasticity) of mixtures. Hesami et al., [5] investigated the impacts of coal waste powder, coal waste ash, and limestone powder on the mechanical properties of roller compacted concrete mixture. The mixtures were prepared by the partial replacement of the cement with the above cementitious materials at different replacement levels of (5, 10 and 20) %. The compressive strength, tensile strength, and flexural strength of roller compacted concrete mixtures were determined at (7, and 90) days. The test results revealed that any further increment of cementitious materials up to 20% substitution of cement exhibits decline in the strength values of the mixtures at all ages. Adamu et al., [6] used high-volume fly ash as partial replacement for cement to prepare roller compacted concrete mixture while nano-silica was implemented as an additive to cementitious materials. The mixtures were tested for compressive, flexural, and splitting tensile strengths. Replacing 53 % of cement with fly ash by volume and the addition of 1.2% of nano-silica by weight of cementitious materials can provide an optimized mixture. However, such mixture exhibits lower compressive, tensile, flexural strength as compared to the control roller compacted concrete mixture. It was revealed that nano-silica partially ignited the pozzolanic activity of fly ash at early ages and can leads to higher performance of roller compacted concrete at early age. Chhorn and Lee, [7] investigated the influence of aggregate gradation, cement content, and some admixtures on the compressive strength of the roller-compacted concrete. It was found that keeping the gradation of aggregate within the recommended limits by the Portland Cement Association is preferred for high compressive strength. The concrete exhibits low sensitivity to water content when the cement binder content is augmented. Strength improvement can be achieved with moisture control during the curing process, and it is possible to extend working time by using admixtures without compromising strength. Barati et al., [8] revealed that 7% micro-silica gel added to the mixture of roller compacted concrete can maximized compressive strength by 43.5 % and 25 % after 7 and 28 days curing respectively. Vahedifard et al., [9] showed that 10% micro silica significantly increased RCCP compressive strength and freeze resistance whereby durability of the pavement against difficult climatic conditions. Mardani and Ramyar [10] used high fly ash content in roller compacted concrete and found that replacing the cement by 40-60% fly ash had reduced compressive, tensile, and flexural strength at all ages. Different roller compacted concrete mixtures were prepared by Saluja et al., [11] for (20, 40, and 60) % replacement of ordinary Portland cement with ground granulated blast furnace slag. The testing results indicated that roller compacted concrete mix containing such additive exhibits lower early age strength as compared to normal concrete while the strength of additive mixes improves with age and provides higher compressive strength compared to normal concrete. Zabihia and Nejad, [12] assessed the improvement of roller compacted concrete using polypropylene fibers and pozzolanic materials (micro silica, limestone, and fly ash). Properties such as flexural and compressive strength have been studies. Based on the results of the tests, it was concluded that Polypropylene fibers cause improvements of the mechanical properties of roller compacted concrete such as compressive strength, flexural strength, and durability against the corrosive environments. Kewalramani and Gupta, [13] revealed that using the NDT method in the evaluation of the compressive strength is faced with some errors and need calibration. The use of mathematical and evolutionary models such as neural networks, fuzzy logic, genetic algorithm and artificial intelligence can be managed based on empirical studies. Compressive strength of roller compacted concrete was investigated by Ranjbar et al., [14] using volumetric weight of materials, coarse aggregate to fine aggregate ratio, and water to cement ratio. The accuracy of the developed models was investigated using correlation coefficient. The experimental stage of the prediction of compressive strength values showed significant accuracy. Comparison of the results showed that the proposed model was capable and in reducing the error rate in the prediction of the compressive strength of roller compacted concrete. Saluja et al., [15] reported that at 28 days, the observed compressive strength of control roller compacted concrete sample (GS0) was highest, indicating that the contribution of blast furnace slag to the strength development was smaller compared to ordinary Portland cement. Rahmani et al., [16] stated that the compressive strength of roller compacted concrete pavement was almost doubled by increasing the W/C ratio from 0.3 to 0.55. Furthermore, with an increase in the cement content from 240 to 340 kg, the compressive strength is also increased by 55%.

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The aim of the present investigation is assessing the influence of additives on the strength property of roller compacted concrete in terms of compressive strength. Gap and dense graded aggregated and (fumed silica, hydrated lime, and fly ash) additives will be implemented in preparation of the roller compacted slab samples. Cube specimens will be extracted from the slab samples and tested in two positions, parallel and perpendicular to the rolling direction for pulse velocity and compressive strength determination.

2. MATERIALS AND METHODS

Portland cement

Ordinary Portland cement Type I as per Iraqi specification No.5, [17] was implemented. The physical properties of the cement are listed in Table 1.

Table 1. Physical Properties of Portland Cement.

Physical Properties	Test Result	Limits of Iraqi specification No.5,[17]
Specific surface area, Blain's method, m^2/kg	341	≥ 230
Soundness, Autoclave's Method, %	0.03	< 0.8
Setting time, Vicat's method		
Initial setting hour : min	2:35	≥ 45 min
Final setting hour : min	4:45	≤ 10 hours
Compressive strength		
3 days N/mm^2	18.8	≥ 15
7 days N/mm^2	23.3	≥ 23

Coarse Aggregates

Crushed aggregates with 25.4 mm nominal maximum size were obtained from Nibae quarry. the properties of coarse aggregates are determined according to ASTM C127, [18]. Test results and listed in Table 2.

Fine Aggregates

Natural fine aggregate with 4.75mm maximum size was obtained from Al-Ukhaider region, the properties of fine aggregates is determined according to ASTM C128, [18] and demonstrated in Table 2.

Table 2. Properties of Coarse and Fine aggregates

Type of aggregate	Bulk Specific Gravity	Density(kg/m^3)	Absorption %	SO3 %
Crushed coarse aggregate	2.56	1600	1	0.06
Fine aggregate	2.45	1780	3.13	0.45

Fumed silica

Fumed silica is supplied as a white, fluffy powder, and obtained from local markets with 10 kg in one sack. Physical properties of fumed silica are listed in Table 3.

Table 3. Physical Properties of Fumed Silica as supplied by the Manufacturer.

Physical Properties	Test result
Specific surface area m^2/kg	170000-230000
Density kg/m^3	202
SiO_2 %(when firing at 1000˚c for 2 hours)	> 99.8
Loss of weight% when drying at 1000˚c for 2 hours	< 2
Loss of weight% when drying at 105˚c for 2 hours	< 1.5
PH	3.9-4.3
% Retained on 40 μm sieve	< 0.04

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Moisture %	0.82

Fly ash

The coal fly ash was obtained from local market, Table 4 demonstrates its physical properties of fly ash.

Table 4. Physical Properties of Fly Ash

Maximum Sieve size (micron)	% Passing	Specific gravity	Specific surface area (m^2/ kg)
0.075	98	2.645	650

Hydrated Lime

Hydrated lime was obtained from local market. The physical properties of hydrated lime are shown in Table 5.

Table 5. The Physical Properties of Hydrated Lime

Chemical Formula	Appearance	Density gm/cm^3	Specific surface area m^2/kg	% Passing Sieve No. 4	Melting point °C
$Ca(OH)_2$	White powder	2.211	4404	100	580

Water

Potable water of Baghdad area is used in RCC mixture preparation and Curing.

Preparation of Dense and Gap Graded Mixtures

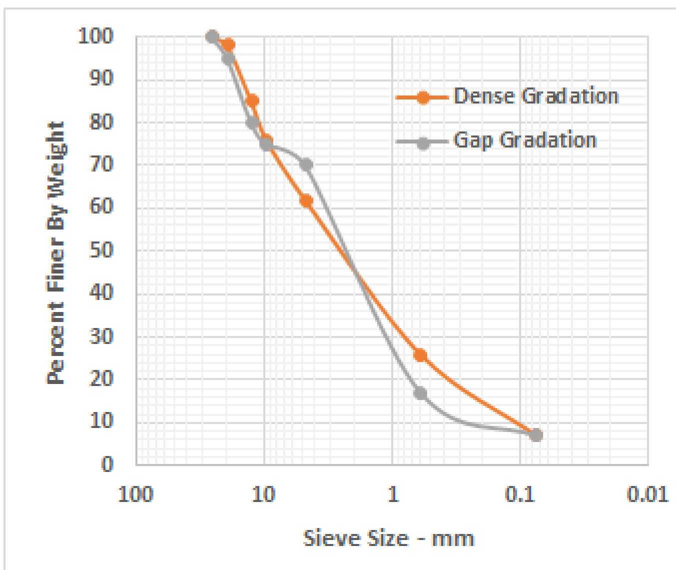

Figure 1. Grain size distribution Implemented.

The coarse and fine aggregates are washed, oven dried, then sieved to different sizes and stored in plastic containers. Aggregates were recombined to satisfy the requirements of gap or dense gradation with 25 mm nominal maximum size of aggregate. The dense gradation satisfies the Iraqi Standard Specification for Roads and Bridges SCRB, [19], while the gap gradation satisfies the British Standards B.S., 882, [20]. The gradation of aggregates for both mixtures is demonstrated in Figure 1. The concrete mix is designed according to ASTM D-1557, [21] standard. This proportioning method involves establishing a relationship between the moisture content and density of the mix by compacting the mix in molds of 101.6 mm diameter and 116.4 mm height. Oven dried coarse and fine aggregates were implemented. Five different percentages of cement content are implemented (10, 12, 14, 16, 18) by weight of oven dried aggregate and six different percentages of moisture content of a range of (4 -8%) with 1% increment are implemented for determination of the dry density-moisture content relationships. After mixing thoroughly by hand, the mixture was poured into cylinder mold in five successive layers. Each layer had practiced 25 blows of the modified Proctor hammer with 4.5 kg weight, falling from 450 mm height according to ASTM D-1557, [21] (modified proctor) test method. Similar procedure was reported by

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Sarsam, [22]. A total of 48-cylinder samples were prepared and the dry density of each specimen was determined. The moisture-density relationship was obtained for each type of mixture. A density-moisture test is implemented to determine the optimum moisture content and maximum density of roller compacted concrete mixtures for each mixture and the optimum cement content was selected to be 12 %. Details of proportioning and mixture design can be referred at Sarsam et al., [23]. Three types of additives (fumed silica, hydrated lime, and fly ash) have been implemented with three percentages for each as partial replacement of Portland cement. Details of optimizing the additives percentages could be referred at Sarsam, [24].

Preparation the Roller Compacted Concrete Samples

The mold used to prepare roller compacted slab samples has internal dimensions of (38 x 38 x 10) cm while the roller has (16cm) diameter and (33cm) length and its self-weight was 36 kg. The required weight of the mixture of aggregates, cement, water, and additives for compacting a slab sample to the target density was combined, mixed, and placed in the mold of size (38× 38 × 10) cm and subjected to initial compaction on a vibrating table for 3 cycles of 30 seconds time interval. Then, the mold was placed in front of the roller compactor and subjected to three stages of rolling based on the work done by Sarsam [23]. Each rolling stage was conducted by applying 10 passes of the roller for each rolling direction. This number of passes was felt to be suitable to achieve the good rolling with lowest labor power. The first stage represents the primary compaction which was performed by applying 10 passes with 1.1 kg/cm width load for each direction. The second stage represents the breakdown compaction which was conducted by applying 10 passes using a load of 3.2 kg/cm width for each direction. The third stage represents the final compaction which is demonstrated by application of 10 passes of the roller compactor under 5.3 kg/cm width load for each direction. The rolling process is demonstrated in Figure 2.

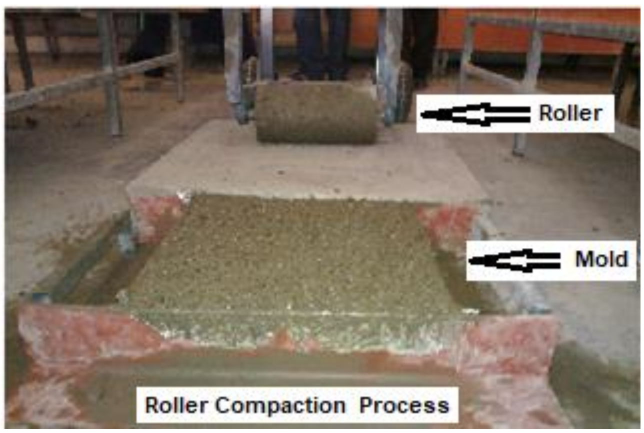

Figure 2. The Roller Compaction Process

After finishing the rolling, the slab sample was covered tightly with polythene sheet and left to cure for 24 hours at room temperature of 30 ± 2°C. The samples were withdrawn from the mold and immersed in a water bath for 27 days for curing at 30 ± 2°C. Sawed cubes specimens of (10 x 10 x10) cm were obtained from the roller compacted slab with the aid of diamond saw according to the procedure by ASTM C42/C42M, [18]. The specimens were subjected to pulse velocity determination according to ASTM C-597, [21], then practiced compressive strength determination using two testing positions, the first position is perpendicular to the rolling compaction process direction while the second position is parallel to the rolling direction. The testing for compressive strength was conducted after 28 days curing according to ASTM, [18].

3. RESULTS AND DISCUSSIONS

Influence of Additives on Compressive Strength

Figure 3 demonstrates the influence of replacement of Portland cement with additives on the compressive strength of the roller compacted concrete specimens tested perpendicular to the direction of rolling compaction. For control mixture (without additives), the compressive strength increases as the cement content increase regardless of the aggregate's gradation type. The compressive strength increases for dense mixes by (67.4 and 101.2) % and for gap mixes by (86.3 and 132.8) % when the cement content changes from (10 to 12 and 16) % respectively.

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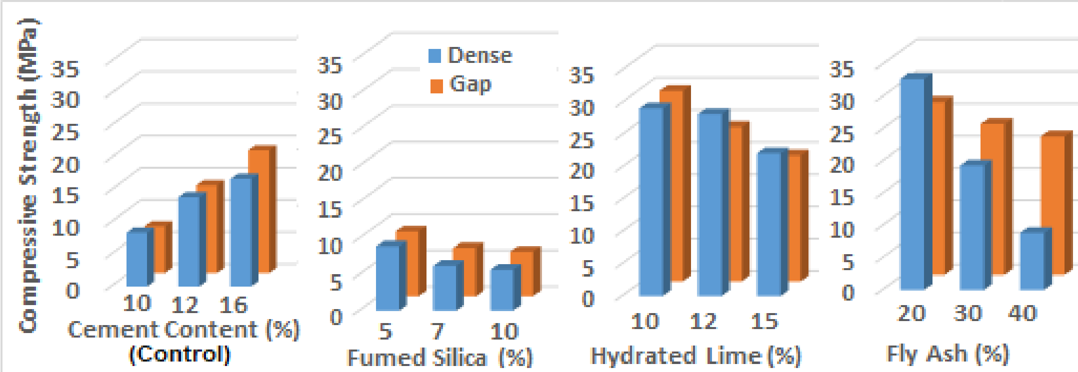

Figure 3. Influence of Additives on the Compressive Strength of the Roller Compacted Concrete

Dense graded mixture exhibits higher compressive strength by (14.5, 2.2, and 1.8) % than gap graded mixture at (10, 12, and 16) % cement content respectively. Such behavior agreed with Chhorn and Lee, [7] and Rahmani et al., [16]. After 28 days of curing, roller compacted concrete mixes should exhibit compressive strength higher than the minimum value of 27.6 MPa required for RCC to be used as surface course as specified in ACI 325.10R [25]. When fumed silica was implemented as partial substitute of Portland cement, the compressive strength declines by (6, 55, and 66.4) % and (18, 50.3, and 64) % at (5, 7, and 10) % replacement of cement by fumed silica for dense and gap gradations respectively. This may be attributed to the higher specific surface area of the fumed silica which absorb more water and the hydration of cement will not be proper. It can be noted that as the percentage of fumed silica increases, the compressive strength decreases. Figure 3 also shows that the influence of gradation type is not significant on compressive strength when fumed silica was implemented as partial substitute of cement. Similar behavior was reported by Vahedifard et al., [9]. When Portland cement was partially replaced with hydrated lime, the compressive strength increases by (229, 103, and 32.3) % and (201, 76.4, and 36.4) % at (10, 12, and 15) % replacement of cement by lime for dense and gap gradations respectively. The lime through the chemical reaction creates cementitious material which increases the compressive strength. However, higher lime content causes reduction in compressive strength of roller compacted concrete, this may be related to the high specific surface area of the lime as compared with that of Portland cement which requires more water for the chemical reaction and hydration. Finally, when fly ash was implemented as partial substitute of Portland cement, the compressive strength increases by (267, 61.7, and 26.4) % at (20, 30, and 40) % replacement of cement by fly ash for gap gradations respectively. However, the compressive strength for dense graded mixtures increases by (201, and 38.8) % at (20 and 30) % replacement of cement by fly ash, while the compressive strength declines by 10.1 % at 40 % replacement of cement by fly ash. Such behavior agrees well with Lam et al., [3].

Influence of testing Position on Compressive Strength

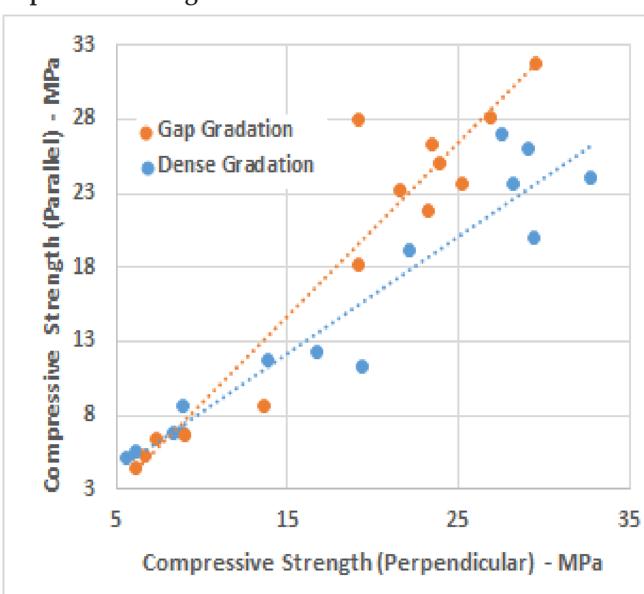

Figure 4. Influence of Testing Position on compressive strength

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Figure 4 demonstrates the influence of testing position of cube specimens on the compressive strength of the roller compacted concrete. The cubes of traditional concrete are usually tested at a position perpendicular to the casting direction. However, in the present assessment, the cube specimens are tested at two positions, perpendicular and parallel to the rolling direction.

It can be noted that for dense graded mixture, higher compressive strength could be detected when the cube specimens are tested at a position perpendicular to the rolling compaction. On the other hand, for gap graded mixture, higher compressive strength could be detected when the cube specimens are tested at a position parallel to the rolling compaction. Table 6 summarizes the mathematical models obtained for the influence of testing position on compressive strength.

Table 6. Mathematical Models for compressive strength

Gradation Type	Mathematical Model for Compressive strength	R^2
Gap	Strength (parallel) MPa = 1.1687 Strength (perpendicular) MPa – 2.8469	0.910
Dense	Strength (parallel) MPa = 0.7885 Strength (perpendicular) MPa – 0.3943	0.913

Influence of testing Position on Ultrasonic Pulse Velocity

Figure 5 exhibits the influence of testing position on ultrasonic pulse velocity of roller compacted concrete cube specimens. It can be detected that dense graded mixture permits higher ultrasonic pulse velocity traversing perpendicular to the direction of rolling. However, gap graded mixtures exhibits mostly higher pulse velocity traversing parallel to the rolling direction. The ultrasonic pulse velocity in the parallel position to rolling is almost two folds higher than that in the perpendicular position for dense graded mixture. This may be related to the preferred orientation of aggregates particles in case of dense gradation under rolling compaction. Table 7 summarizes the mathematical models for ultrasonic pulse velocity through roller compacted concrete.

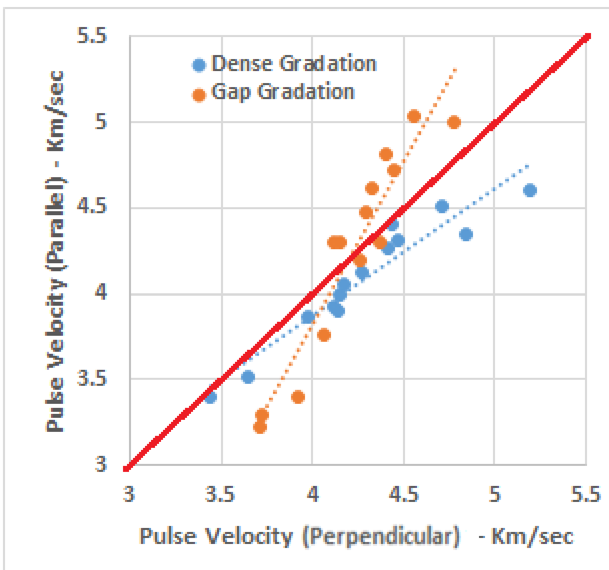

Figure 5. Influence of Testing Position on Ultrasonic Pulse Velocity

Table 7. Mathematical Models for Ultrasonic Pulse Velocity

Gradation	Mathematical Model for Ultrasonic Pulse Velocity	R^2
Gap	Pulse velocity (parallel) km/sec = 1.909 Pulse velocity (perpendicular) km/sec – 3.820	0.903
Dense	Pulse velocity (parallel) km/sec = 0.737 Pulse velocity (perpendicular) km/sec – 0.926	0.912

4. CONCLUSIONS

Based on the limitations of materials and the executed testing program, the following conclusions are addressed.

1- Dense graded mixture exhibits higher compressive strength by (14.5, 2.2, and 1.8) % than gap graded mixture at (10, 12, and 16) % cement content respectively.

2- The compressive strength declines by (6, 55, and 66.4) % and (18, 50.3, and 64) % at (5, 7, and 10) % replacement of cement by fumed silica for dense and gap gradations respectively.

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3- The compressive strength increases by (229, 103, and 32.3) % and (201, 76.4, and 36.4) % at (10, 12, and 15) % replacement of cement by lime for dense and gap gradations respectively.

4- The compressive strength increases by (267, 61.7, and 26.4) % at (20, 30, and 40) % replacement of cement by fly ash for gap gradations respectively. However, the compressive strength for dense graded mixtures increases by (201, and 38.8) % at (20 and 30) % replacement, while it declines by 10.1 % at 40 % replacement of cement by fly ash.

5- Higher compressive strength could be detected when the cube specimens are tested at a position perpendicular to the rolling compaction for dense graded mixture, while higher compressive strength could be detected when the cube specimens are tested at a position parallel to the rolling compaction for gap graded mixture.

6- Dense graded mixture permits higher ultrasonic pulse velocity traversing perpendicular to the rolling direction. However, gap graded mixtures exhibits mostly higher pulse velocity traversing parallel to the rolling direction.

7- Hydrated lime and fly ash are recommended as additives for partial substitution of Portland cement in roller compacted concrete from compressive strength point of view.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Ashrafian A., Gandomi A., Rezaie-Balf M., Emadi M. An evolutionary approach to formulate the compressive strength of roller compacted concrete pavement. Measurement, Volume 152, February. 2020. 107309.
2. Vahedifard, F., Nili, M., and Meehan, C. L. Assessing the effects of supplementary cementitious materials on the performance of low-cement roller compacted concrete pavement. Construction and Building Materials, 24(12), December. 2010. P. 2528–2535.
3. Lam, M. N., Duc-Hien, L., and Jaritngam, S. Compressive strength and durability properties of roller-compacted concrete pavement containing electric arc furnace slag aggregate and fly ash. Construction and Building Materials, 191, December. 2018, P. 912–922. Elsevier.
4. Ashteyat A., Al Rjoub Y., Murad Y., Asaad S. Mechanical, and durability behavior of roller-compacted concrete containing white cement bypass dust and polypropylene fiber. European Journal of Environmental and Civil Engineering. 2019.
5. Hesami, S., Modarres, A., Soltaninejad, M., & Madani, H. Mechanical properties of roller compacted concrete pavement containing coal waste and limestone powder as partial replacements of cement. Construction and Building Materials, 111, May 2016. P. 625–636.
6. Adamu, M., Mohammed, B. S., & Mohd, S. L. Mechanical properties and performance of high-volume fly ash roller compacted concrete containing crumb rubber and nano silica. Construction and Building Materials, 171, May. 2018. P. 521–538.
7. Chhorn C., and Lee S. Influencing compressive strength of roller-compacted concrete. Proceedings of the Institution of Civil Engineers - Construction Materials. Volume 171, Issue 1 February. 2018.
8. Barati R., Sahaf S., Jamshidi M., and Razazpor A. Examining the Impact of Micro Silica Gel Additive on the Compressive Strength and Water Absorption of Roller Compacted Concrete Pavement. Modern Applied Science; Vol. 10, No. 5; 2016. Canadian Center of Science and Education.
9. Vahedifard, F., Nili, M., & Meehan, L. Assessing the effects of Supplementary Cementitious Materials on The Performance of Low-Cement Roller Compacted Concrete Pavement. Construction and Building Materials, 24(12), 2010.P. 2528-2535.
10. Mardani, A. and Ramyar, K. Mechanical Properties of High-Volume Fly Ash Roller Compacted Concrete Designed by Maximum Density Method. Construction and Building Materials, 38, 2013. P. 356-364.
11. Saluja S., Goyal S. and Bhattacharjee B. Strength properties of roller compacted concrete containing GGBS as partial replacement of cement. Journal of Eng. Research Vol. 7 No. (1) March. 2019. P. 1 – 17.
12. Zabihia R. and Nejad J. Investigating the strength indices of roller compacted concrete containing propylene fibers for

© 2021 Discovery Scientific Society. All Rights Reserved. ISSN 2319–7757 EISSN 2319–7765 I OPEN ACCESS

the pavement of roads. QUID. 2017, P. 475-483, Special Issue No.1- Medellín-Colombia.
13. Kewalramani M. and Gupta R. Concrete compressive strength prediction using pulse velocity through artificial neural networks. Elsevier, Automation in Construction, 15, 2006.
14. Ranjbar A., Barahmand N., Ghanbari A. Hybrid Artificial Intelligence Model Development for Roller-compacted Concrete Compressive Strength Estimation. IJE Transactions A: Basics Vol. 33, No. 10, October. 2020. P.1852-1863.
15. Saluja S., Goyal S., and Bhattacharjee B. Strength properties of roller compacted concrete containing GGBS as partial replacement of cement. Journal of Eng. Research Vol. 7 No. (1) March. 2019. P. 1-17.
16. Rahmani E., Sharbatdar K., Beygi M. A comprehensive investigation into the effect of water to cement ratios and cement contents on the physical and mechanical properties of Roller Compacted Concrete Pavement (RCCP). Construction and Building Materials 253, 2020. 119177. Elsevier.
17. Iraqi Organization of Standards, 1984. IOS 5: 1984, for Portland cement.
18. ASTM, American Society for Testing and Materials, ASTM: Road and Paving Material, Vehicle- Pavement System, Annual Book of ASTM Standards, Vol. 04.03. 2016.
19. SCRB, State commission of roads and bridges, Standard specifications for roads and bridges. Ministry of Housing, and Construction, 2003. Iraq.
20. British Standard 882. Concrete Aggregates, British Standards Institution, London, 1965.
21. ASTM D-1557, Standard Test Method for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10Ib (4.54 kg) Hammer and 18-in. (457-mm) Drop, Annual Book of ASTM Standards American Society for Testing and Materials. 04(8): 2002. P. 206–210.
22. Sarsam S. Evaluation of Roller Compacted Concrete Pavement Properties, Engineering and Development, Scientific Journal of AL-Mustansiriah University, 6. 2002. P.59-74.
23. Sarsam S., Salih A., Ghazi S. Effect of Hydrated Lime on the Properties of Roller Compacted Concrete. Journal of Engineering Number 3 Volume 19 March. 2013, P. 377-387.
24. Sarsam S. I. Assessing the Influence of Aggregates and Cement Types on Fresh Roller Compacted Concrete Mixture. International Research Journal of Multidisciplinary Technovation, Vol 3, Issue 3, 2021. Asian research Association. P. 23-31.
25. ACI 325.10R, 95th Edition, 2001 - Report on Roller-Compacted Concrete Pavements.

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