SUSTAINABLE DEVELOPMENT OF CONCRETE CONSTRUCTION

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ABSTRACT - Sustainability is important to the well-being of our planet, continued growth of a society, and human development. Concrete is one of the most widely used construction materials in the world. However the production of portland cement, an essential constituent of concrete, leads to the release of significant amounts of CO2, a greenhouse gas (GHG); production of one ton of portland cement produces about one ton of CO2 and other GHGs. The environmental issues associated with GHGs, in addition to natural resource issues, will play leading role in the sustainable development of cement and concrete industry during this century. For example, as the supply of good-quality limestone to produce cement decreases, producing adequate amounts of portland cement for construction will become more difficult. There is a possibility that when there is more good-quality limestone in, say, a geographical region, and thus portland cement, all the employment associated with the concrete industry, as well as new construction projects, will be terminated. Because of limited natural resources, concern over GHGs, or, both, cement production is being curtailed, or at least cannot be increased to keep up with the population increase, in some regions of world. It is therefore necessary to look for sustainable solutions for future concrete construction. A sustainable concrete structure is constructed to ensure that the environmental impact during its life cycle, including its use, will be minimal. Sustainable concrete should have very low inherent energy requirement, be produced with little waste, be made with recycled materials. Sustainable constructions have a small impact on the environment. They use "green" materials, which have low energy costs, high durability, low maintenance requirements, and contain a large proportion of recycled or recyclable materials.

KEYWORDS- Sustainability, Concrete, GHGs, Portland cement, Aluminium Powder, Fly ash, Sand and Cement.

I. INTRODUCTION

The potential use of Recycle Concrete Aggregate (RCA) has been explored previously, but its use with fly ash in concrete pavement has not been thoroughly studied. The application of RCA in concrete started in the U.S. in 1942 by using demolished concrete pavement as recycled aggregate for stabilizing the base materials for road construction . Applying the use of fly ash, Kou quantified the advantages of using fly ash as an additional cementitious material in RCA to improve workability and durability . The workability and durability of RCA concrete mixes can also be improved by using fly ash. The advantages of using RCA and fly ash are of sustainable and environmental concern. The large volumetric in-waste or by-product materials from industry are going to landfills and have been increasing with time. Sustainable materials are one of the strategies to be considered by the construction industry to help circumvent this problem. A couple of ways to achieve the goal of reducing volumetric in waste is to utilize RCA from the largest sources of such waste such as construction and demolition projects, and fly ash from burning coal in the production of concrete. This is the primary impetus for the recycled materials of concrete pavement in the form of RCA and fly ash, and has become an obvious choice for concrete pavement. Subsequently there is a need to assess the performance of RCA with fly ash for use in concrete pavement. The input parameters required for critical response computation with use of the Mechanistic-Empirical Design Guide of new and rehabilitated pavement structures are: elastic modulus,

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Poisson's ratio, and modulus of rupture.

A concrete pavement road must sustain many load cycles through its lifespan. Accordingly, the objective of this study is to evaluate material properties of concrete containing varying amounts of fly ash and/or RCA. The first parameter to be evaluated will be compressive strength. The next parameter to be 13 evaluated will be the elastic modulus. The concrete must have an adequate elastic modulus. . Another important parameter to be evaluated will be flexural strength.

II. LITERATURE REVIEW

Jonny Nilimaa-Smart materials and technologies for sustainable concrete construction

This paper presents a comprehensive review of current trends and opportunities for sustainable concrete construction, emphasizing the importance of adopting eco-friendly practices to mitigate the industry's environmental impact. Green concrete, supplementary cementitious materials, permeable concrete, cool concrete, and the use of local materials are explored as sustainable materials and technologies.

Rasha A. Ali ,Omar H. Kharofa - The impact of nanomaterials on sustainable architectural applications smart concrete as a model

This paper discusses the use of nanomaterials in sustainable architectural applications by focusing on concrete which , despite its structural efficiency , has been subjected to a lot of criticism from the owners of an environmental orientation that respects and emulates nature, nanotechnology has contributed to improving this material, so it has modified it from an unacceptable material to many specialists to a sustainable material dealing with specific architectural features of the building and contributes to its enrichment, such as aspects of energy, environment, insulation, expression, complementarity, compatibility and others.

Hadi Bahmani, Davood Mostofinejad - A novel high-performance concrete based on calcium oxide-activated materials reinforced with different fibers

In this study, a high-performance concrete based on calcium oxide-activated materials was developed and studied. Calcium chloride and calcium nitrate additives were used to improve the microstructure of such concrete. In addition, different fibers including steel, recycled PET, basalt, glass, and modified synthetic macro fibers were used to overcome the brittleness of the HPC-CAM geopolymer matrix. Compressive, flexural, water absorption, scanning electron microscopy (SEM), and Fourier transform infrared spectroscopy (FTIR) tests were performed to evaluate the overall characteristics of the specimens thus prepared. The results showed that adding calcium chloride and calcium nitrate increased the compressive strength of HPC-CAM by 69% and 29%, respectively.

Ehab T. Al-Rousan , Hammad R. Khalid , Muhammad Kalimur Rahman - Fresh, mechanical, and durability properties of basalt fiber-reinforced concrete (BFRC)

Basalt fiber-reinforced concrete (BFRC) is relatively a new type of fiber-reinforced concrete, which has demonstrated good mechanical performance. Several types of fibers such as steel, glass, and carbon fibers, are used to improve the performance of plain concrete. However, basalt fibers (BF) are being considered superior to these because of their comparable mechanical strength, higher durability than glass fibers, lesser cost than carbon fibers, sustainability due to abundant raw material, and environment-friendly production process. Hence, the number of studies on BFRC are increasing over the years. This review paper covers the properties of BF and BFRC. The effects of BF length and dosage are discussed in detail in term of fresh, hardened, and durability properties of BFRC, followed by highlighting some areas for future research. It is concluded that BF can potentially replace the other conventional fibers which are being used in the industry.

Lateef Assi ,Kealy Carter , Edward (Eddie) Deaver , Rafal Anay ,Paul Ziehl - Sustainable concrete: Building a greener future

In an effort to reduce waste and engage in more sustainable construction, this research focuses on the development of a cost-competitive, environmentally-friendly geopolymer concrete mixture that offers structural benefits relative to ordinary Portland cement (OPC), uses fly ash, a toxic waste byproduct as a raw material, and reduces the amount of CO_2 emitted during production of the concrete.

III. METHODS AND METHODOLOGY

Two batches of concrete were produced with two different w/c ratios at 0.55, and 0.45 in the laboratory. The first batch has two types of length of curing time. Type I is for short length of curing time (14, 28, and 56 days). Type II is for long length of curing time (56, 72, and 112 days of age). Both types contain four different concrete mixes with w/c ratio of 0.55 (Table 3.1). It is identified as (1) 0.5 control mix, (2) 0.55 R-25-F0, (3) 0.55 R25- F10, and (4) 0.55 R25-F15. The second batch contains four different concrete mixes with w/c ratio of 0.45 with the same identifications as well with 0.45 water/cement ratio.

A. *Material Selection*

- Recycled concrete aggregate can be easily obtained from demolished structures which are comprised largely of broken members. Properties of these broken concrete materials such as type of admixtures, aggregate origins and gradations, as well as the differentiation of its properties during the performance time are often unknown, historical data need to be

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consulted. These data were categorized into three general areas: physical characteristics, mechanical

IV. Concrete Mix Preparations

Selection of water/cement ratio is the most critical parameter for controlling the concrete strength. Maintaining the water content for design the concrete mix is one key for achieving good long term performance of the concrete. There is an excellent correlation between w/c ratio and compressive and flexural strength. Hansen concluded that the w/c ratio is valid for recycled aggregate concrete as it is for concrete made with virgin materials, but only the level of strength development would be reduced [18]. To produce a similar workability, we found that 5% more water was required for a recycled coarse aggregate concrete [27]. Therefore, the w/c ratio of 0.55, and 0.45 were selected to design concrete mixtures containing RCA with a target of 4500psi, and 5500psi strength respectively.

The specific gravity and water absorption of virgin 26 aggregates and RCA are shown in Table 3.2, and Table 3.3, respectively. The mix proportions for these mixes are shown in Table 3.4. This study is concerned with investigating the feasibility of using RCA and fly ash in concrete for pavement applications. The concrete mix preparation was performed at room temperature in a ventilated area. The specimens' preparation includes preparing mix ingredients, mixing, casting specimens, and curing. The content of each mix component is determined by the weight ratio of the component to total aggregates.

V. EXPERIMENTAL WORK

A combined total of twelve mixes of 108 cylindrical specimens for compressive strength, and modulus of elasticity tests; and 48 beams were prepared for flexural strength testing in this study. The compressive strength test is a routine test to evaluate another mechanical property of concrete. The test results can be used as a basis for quality control of concrete. The standard ASTM C-39 test procedure was followed in running the compressive strength on the 4 in. ×8 in. cylindrical specimens [35]. The ends of the specimens were capped before testing to ensure even loading during testing. Calibration of the linear variable displacement transformer (LVDT) gage that holds linear variable differential transformer is required. The gage is mounted to the test specimen at two points between which displacement is to be measured.

Two beams of each batch mixtures were tested at 28 day, 56 days with w/c ratio 0.55 for Batch I-Type I, at 28, 56 days for Batch I-Type II, and at 72, 112 days with w/c ratio 0.45 for Batch II. Before each beam is placed in the testing machine, draw a reference line on the top and bottom of the beam, as cast, about 1.5 in from each end of the specimen. The two reference lines should be exactly opposite to each other. A line drawn across the bottom of the beam when placed in the machine, will meet these two lines, and will be perpendicular to them

RESULTS AND DISCUSSION

Compressive Strength

The average compressive strengths of nine concrete mixtures at various curing periods after 14, 28, and 56 days of Batch I-Type I are presented in Tables 4-1; and 56, 72, and 112 days of Batch I-Type II are presented in Table 4.2; 56, 72, 112 days of Batch II are presented in Table 4.3. The individual compressive strength values are shown in Appendix C. Figure and Figure show the compressive strength progression for all specimens of Batch I, and II. It can be seen that these fly ash mixes continue to increase in compressive strength up to 112 days.

Table 4.1. Average Compressive Strength Test Results Batch I-Type I

Batch	ID of Specimens	Length of Curing (days)		
		14 Compressive Strength (psi)	28 Compressive Strength (psi)	56 Compressive Strength (psi)
I	0.50 Control (T-I)	4520	4836	5122
	0.55 R25-F0 (T-I)	4443	4711	5089
	0.55 R25-F10 (T-I)	4480	4789	5195
	0.55 R25-F15 (T-I)	4344	4790	5203

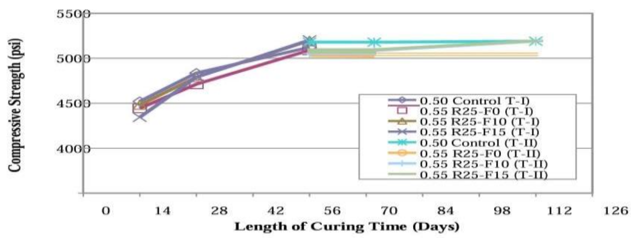
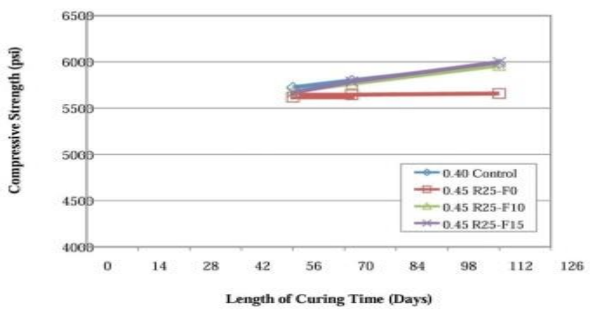


Table 4.2. Average Compressive Strength Test Results Batch I-Type II

Batch	ID of Specimens	Length of Curing (days)		
		56 Compressive Strength (psi)	72 Compressive Strength (psi)	112 Compressive Strength (psi)
I	0.50 Control (T-II)	5178	5180	5190
	0.55 R25-F0 (T-II)	5025	5030	5046
	0.55 R25-F10 (T-II)	5053	5085	5190
	0.55 R25-F15 (T-II)	5068	5096	5193



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Modulus of Elasticity

According to ACI Code 318, the experimental measured values of elastic modulus of all concrete mixes have lower values than the estimated values based on ACI relation of all concrete mixture.

Table 4.4. Average Modulus of Elasticity Test Results Batch I-Type I

Batch	ID of Specimens	Length of Curing (days)					
		14 Elastic Modulus ($x10^6$ psi)		28 Elastic Modulus ($x10^6$ psi)		56 Elastic Modulus ($x10^6$ psi)	
		M. V	E.V	M. V	E.V	M. V	E.V
I	0.50 Control	4.02	4.08	4.02	4.22	4.02	4.34
	0.55 R25-F0	3.86	4.00	4.02	4.12	4.02	4.28
	0.55 R25-F10	3.86	4.02	4.00	4.15	4.00	4.33
	0.55 R25-F15	3.89	3.96	4.00	4.15	4.00	4.33

Note: M.V is Measured Values and E.V. is Estimated Values

Table 4.5. Average Modulus of Elasticity Test Results Batch I-Type II

Batch	ID of Specimens	Length of Curing (days)					
		56 Elastic Modulus ($x10^6$ psi)		72 Elastic Modulus ($x10^6$ psi)		112 Elastic Modulus ($x10^6$ psi)	
		M. V	E.V	M. V	E.V	M. V	E.V
I	0.50 Control	4.10	4.36	4.05	4.36	4.09	4.37
	0.55 R25-F0	4.02	4.26	4.06	4.25	4.20	4.26
	0.55 R25-F10	4.20	4.27	4.10	4.28	4.10	4.32
	0.55 R25-F15	4.05	4.27	4.00	4.28	4.05	4.33

Effects of RCA and Fly Ash on Compressive Strength

Batch I-Type I, at a fixed 0.55 water/cement ratio and a length of curing time of 14 days, the compressive strength is lower by 1.7%, 0.8%, and 4.1% respectively for the three concrete mixes:ID 0.55 R25-F0, 0.55 R25-F10, and 0.55 R25-F15 as compared with the 0.5 control mix. At 28 days, the compressive strength is lower by 2.6%, 0.9%, and 0.9% respectively for the concrete mixes: ID 0.55 R25-F0, 0.55 R25-F10, and 0.55 R25-F15, as compared with the 0.5 control mix. At 56 days, the compressive strength is lower by 0.6% with concrete mix ID 0.55 R25-F0, it increases by 1.4% with concrete mix ID 0.55 R25-F10, and 1.5% with concrete mix ID 0.55 R25-F15 as compared to the 0.5 control mix. The analysis shows a comparison of compressive strength of four concrete mixes Batch I-Type I. The diagram indicates that three concrete mixtures with ID: 0.55 R25-F0, 0.55 R25-F10 and 0.55 R25-F15 have lower strength at 14, and 28 days of age, as compared to the 0.5 control mix, but concrete mixes with ID 0.55 R25- F10, 0.55 R25-F15 started increasing in compressive strength at 56 days. This shows that concrete mixes containing fly ash increase in compressive strength above that of the control mix with length of curing times of 56 days or more

Effects of RCA and Fly Ash on Modulus of Elasticity

Figures 5.4 - 5.6 present the results of the elastic modulus test. At short length of curing times, it can be seen no significant change exist in the elastic modulus of concrete in the concrete mixes containing RCA and varying amounts of fly ash. Batch I-Type I, at a fixed 0.55 water/cement ratio and a length curing time of 14 days, the elastic modulus is lower by 4.1%, 4.1%, and 3.3% respectively for the three concrete mixes: ID 0.55 R25-F0, 0.55 R25-F10, and 0.55 R25-F15 as compared with the 0.5 control mix. At 28, and 56 days, the elastic modulus remains unchanged for concrete mixture ID 0.55 R25- F0, and is lower by 0.5% for the two concrete mixes: ID 0.55 R25- F10, and 0.55 R25-F15 respectively as compared with the 0.5 control mix. This shows that concrete mixes containing 10% and 15% fly ash exhibit a decrease in elastic modulus of 0.5% when compared with concrete mixes containing RCA only for shorter length of curing times.

Effects of RCA and Fly Ash on Flexural Strength

Figures 5.7 - 5.9 present the analysis of the flexural strength tests. They show no significant change in the flexural strength in concrete with RCA and fly ash added but strength slightly increases with the percentage of fly ash.

VI. CONCLUSION

This purpose of this study was to evaluate the feasibility of using concrete containing Recycled Concrete Aggregate (RCA) and fly Ash (FA) for use in low- modulus concrete pavement applications. Results of the laboratory testing program indicate that the compressive strength was the same after 72 days of length of curing time for the two different concrete mixes containing RCA with 10%, and 15% fly ash compare with control mix at water/cement ratios 0.5, and 0.4. The elastic modulus slightly decreases for all three different concrete mixes containing RCA and fly ash of two batches at 14, 28 days. At 56 days concrete mixes containing RCA have the same value of elastic modulus as the control mixes in the two batches. At 112 days of curing duration, the elastic modulus is slightly lower for concrete mixes containing RCA and fly ash of Batch II, and has the same elastic modulus for concrete mixes containing RCA and fly ash of Batch I-Type II. The flexural strength slightly decreases for all concrete mixes of the two batches before 56 days of length of curing time. The flexural strength is still lower after 56 days up to 112 days of length of curing time for concrete mixes containing RCA of Batch I, and concrete mixes containing RCA and fly ash of Batch II as compared to the control mix in the two batches. However, the flexural strength increases after 72 days of length of curing time for concrete mixes containing RCA and fly ash in Batch I, and has the same value of flexural strength as the control in Batch I. After analysis, it has been determined that the concretes containing RCA and fly ash have the same strength after 112 days of length of curing time as the control mix at 0.5 and 0.4 water/cement ratio. With the use of RCA up to 25%, and fly ash up to 15%, there will not be a significant difference (if any) in strength compared with concrete

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containing virgin aggregate and Type I, Portland cement. Thus the main advantages of using RCA and fly ash are the economical and environmental benefit.

The results of this limited laboratory testing program are that the use of RCA as aggregate replacement, and fly ash as cementitious replacement in concrete pavement appears not only to be viable but extremely resourceful as well. It is thus recommended that further research be conducted in this area to further validate this finding.

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