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Statistical models for concrete containing wood chipping as partial replacement to fine aggregate

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HIGHLIGHTS

- Wood chipping can be used as lightweight aggregate for the production of lightweight concrete.
- Utilization of wood chipping as partial replacement to sand in concrete is feasible and appropriate.
- Different wood chipping percentages in concrete were studied and evaluated.
- Statistical models were developed and validated to provide a design mix aid of concrete containing wood chipping.

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ABSTRACT

The properties of concrete containing wood chippings as partial replacement to fine aggregate are presented in this paper. Wood chipping was treated by water before mixing to prevent it from soaking the water meant for cement hydration. Fifteen trial mixes were prepared and cast using three water–cement ratios (0.37, 0.41 and 0.57) at different replacement levels of wood chippings. Fresh concrete properties tested included slump, unit weight and air content. Hardened concrete properties tested included compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, rebound hammer (RH) and ultrasonic pulse velocity (UPV). Several statistical models were developed to show the relationships between measured responses and variables and among measured responses. These models were validated using various model statistics. Test results show that disposal of wood chipping in concrete is feasible and appropriate. These models are providing a design mix aid of concrete containing wood chipping as partial replacement of fine aggregate.

1. Introduction

Increase in population has created greater demand on construction material which leads to a chronic shortage of building materials and thereby increases the construction cost. To alleviate this problem, engineers are not only challenged with the future home-building in terms of construction cost control but also the need to convert the industrial wastes to useful construction and building materials. One of such ways is to introduce industrial waste material into concrete. Such waste materials are wood chipping, paper mill, crumb rubber and palm oil clinker. The utilization of these waste reduce the use of aggregate from natural sources and ensures sustainability [1,2].

Concrete containing waste wood product as aggregates is one kind of lightweight concrete. The advantages of lightweight concrete are higher strength-to-weight ratio, better tensile strain capacity, lower coefficient of thermal expansion, and superior heat and sound insulation [3–5]. In addition, the using of lightweight concrete will cause a reduction in the building cost, ease the construction and has the advantage of being a relatively 'green' building material [6]. However, lightweight concrete has its associated disadvantages, such as low workability and lower indirect tensile strength. The problems arising from these shortcomings have been dealt with through adding of mineral admixtures and superplastizer to concrete mixture to obtain higher workability [4,7].

Several researches have studied the utilization of waste wood product as lightweight aggregates [5,8–12]. It has been reported that concrete containing wood waste can be produced as structural lightweight concrete with a good thermal conductivities compared to sand concrete without wood waste [10]. Besides, concrete containing wood waste displays a reasonable strength and durability and complies with class III RILEM specification for lightweight concrete [11]. Though, adverse effects of inclusion of waste wood in concrete such as reductions in the strengths of the hardened

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concrete have also been reported [5,11], however, suggestions on treatment of waste wood before inclusion in concrete to overcome the strength reductions have been made [6,11,12].

Although many experimental works have been carried out to establish the fresh and hardened properties of the concrete containing waste wood as aggregate, yet no models have been introduced to predict the properties of such concrete. Therefore, the main aim of the work presented in this paper is to establish statistical models to predict the properties of concrete containing wood chipping as a partial replacement to fine aggregate.

2. Materials

2.1. Portland cement, fine and coarse aggregates

The cement used in all mixtures was Portland cement (PC) type I, which conform to the requirement of ASTM C150. The coarse aggregate used were crushed stone graded as a 9.5 mm nominal maximum size, with a bulk density of 1571 kg/m^3, a specific gravity of 2.28, and 0.81% absorption. The fine aggregate (river sand) had a bulk density of 1573.6 kg/m^3, a specific gravity of 2.34, 7.88% absorption, and a fineness modulus of 2.45. Physical properties of coarse and fine aggregate were performed according to ASTM C127 and ASTM C128, respectively.

2.2. Wood chippings

The wood chipping used in this study is generated in the factory from the mechanical processing of raw wood in the sawing process, with bulk density of 257.7 kg/m^3, a specific gravity of 0.288, and 290.2% absorption.

3. Mixture proportions

The mixture proportions and fresh properties of the concrete mixtures produced in the laboratory are shown in Table 1. A total of 15 concrete mixtures were produced. Three water cement ratio had been used, 0.37, 0.41, and 0.57. Four levels of wood chipping partially replaced to fine aggregate by volume, 10%, 15%, 20% and 30% for each water cement ratio. Additional water at each specified water cement ratio required due to higher water absorption of wood chipping (290.2%) to produce workable concrete mixtures. Table 2 shows the amount of additional water needed. Eq. (1) used to calculate the additional water added.

$$Mass\,of\,additional\,water = \frac{Difference\,in\,absorption}{100} \times mass\,of\,wood\,chipping \quad (1)$$

where difference in absorption = absorption of wood chipping – absorption of sand.

Table 2
Amount of additional water at various water–cement ratio and percentage replacement of sand by wood chipping.

w/c Ratio	Wood chipping replacement by volume (%)	Wood chipping replacement (kg/m^3)	Mass of additional water (kg/m^3)
0.37	0	0	0
	10	4.857	13.72
	15	7.288	20.58
	20	9.715	27.44
	30	14.57	41.15
0.41	0	0	0
	10	12.71	35.89
	15	19.01	53.68
	20	25.41	71.45
	30	38.11	107.61
0.57	0	0	0
	10	14.17	40.01
	15	21.26	60.03
	20	28.32	79.96
	30	42.50	120.00

4. Experimental program

After mixing and before the concrete were poured into the mould, slump, unit weight and air content tests were conducted. From each concrete mixture, 100 mm cubic specimens were cast to determine the compressive strength, 150 × 300 mm cylinders were cast for the compressive strength, splitting tensile strength, modulus elasticity, and non-destructive tests, 100 × 100 × 500 mm prisms were cast for the flexural strength tests. Table 3 shows the number of specimens and test standards.

4.1. Fresh concrete tests

The slump tests were performed according to ASTM C143 on all the concrete mixtures to determine the consistency and workability. The air content and unit weight tests were performed using gravimetric methods according to ASTM C138.

4.2. Hardened concrete tests

Mechanical properties were investigated to determine the compressive, splitting tensile, flexural and static modulus of elasticity. Non-destructive tests (Rebound hammer and ultrasonic pulse velocity tests) were also carried out. The mechanical

Table 1
Mix proportion at different water–cement ratio.

w/c Ratio	Wood chipping replacement		Cement (kg/m^3)	Fine aggregates (kg/m^3)	Coarse aggregates (kg/m^3)	Water (kg/m^3)	Air content (%)	Slump (mm)	Unit weight (kg/m^3)
	%	kg/m^3							
0.37	0	0	656.76	297.18	801.21	243	7	30	1915.43
	10	4.857	656.76	267.43	801.21	243	10.1	110	1808.00
	15	7.288	656.76	252.12	801.21	243	11.7	150	1754.64
	20	9.715	656.76	237.30	801.21	243	14	180	1687.84
	30	14.57	656.76	207.64	801.21	243	19	210	1554.15
0.41	0	0	592.68	775.96	673.35	243	9.1	50	1889.96
	10	12.71	592.68	698.36	673.35	243	12.3	135	1733.99
	15	19.01	592.68	659.50	673.35	243	14.3	175	1649.64
	20	25.41	592.68	620.79	673.35	243	16.7	210	1562.11
	30	38.11	592.68	543.21	673.35	243	21.3	240	1402.16
0.57	0	0	426.32	865.00	750.65	243	11.3	72	1836.65
	10	14.17	426.32	778.46	750.65	243	14.8	175	1660.78
	15	21.26	426.32	735.19	750.65	243	17.4	220	1563.70
	20	28.32	426.32	692.07	750.65	243	19.7	245	1476.96
	30	42.50	426.32	605.52	750.65	243	23.6	260	1328.15