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Environmental friendly concrete using giant reed as undesirable wild species

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ABSTRACT

Giant reed is an aggressive agricultural species with remarkable reproductive abilities allows it to out compete native species of plants for land and food resources. In this study, a novel application of giant reed ash (GRA) to partially replace the fine aggregate by 2.5, 5.0, 7.5, 10.0, and 12.5% in concrete mixes was investigated. The influence of giant reed on the fundamental mechanical properties of concrete mixes was analyzed. Curing ages of 7, 14, and 28 days were applied in this study. Results revealed an increase in the compressive and flexural strengths up to 7.96 and 7.28%, respectively when giant reed replaced the sand by 7.5% by weight. From environmental perspective, the results confirmed that using GRA offers a sustainable approach to solve the pollution problems arise from the accumulation of this excessive aggressive species in the production sites; in the meantime modified properties were added to the concrete.

Keywords: Giant reed, Concrete, Compressive strength, Fine aggregate, Workability.

INTRODUCTION

Giant reed is a cane like perennial grass which forms massive clumps that expand through rhizomatous growth into dense thickets. It has a fast growth rate and can grow to as much as meters in height within the growing season. It is an aggressive invader of riparian areas throughout many sub-tropical regions of the world, and is hypothesized to provide poorer quality habitat for native wildlife in riparian systems (Herrera & Dudley, 2003).
Giant reed is native to India, but has been widely introduced as an ornamental and for bank stabilization. Subsequently, it has become naturalized and invasive in many tropical, subtropical, and warm-temperate regions of the world (Dudley et al., 2000). A significant volume of giant reed exists worldwide, in particular in the Mediterranean coastal area. Today the giant reed calls most of the western United States, South-East Asia, and European area (Fuller & Barbe, 1985; Bell, 1993). Giant reed is a severe threat to riparian areas where it displaces native plants and animals by forming massive stands that pose a wildfire threat

(Frandsen & Jackson, 1994). It also alters channel morphology by retaining sediments and constricting flows and may reduce stream navigability (Dudley et al., 2000). Giant reed's ability to spread over geographic locations quickly, via natural waterways, allows it to overtake large areas very quickly making giant reed extremely undesirable. On the other hand, concrete has emerged as the dominant construction material for the infrastructure needs of the twenty-first century. In addition to being durable, concrete is easily prepared and fabricated from readily available constituents and is therefore widely used in all types of structural systems. Thus, the continuous reduction of natural resources and the environmental hazards posed by the disposal of coal ash has reached alarming proportion such that the use of waste materials in concrete manufacture is a necessity than a desire. In this regard, extensive research work was accomplished using several types of waste materials including but not limited to plastic, glass, fly ash, and technologic waste as additives or to replace the aggregate (Ismail & Al-Hashmi, 2008; Ismail & Al-Hashmi, 2009; Bentz et al., 2011; Malaiškiene et al., 2011). However, none of these researches dealt with the application of the undesirable wild giant reed in concrete mixes as a dumping media. This research work aimed to study the basic strength properties of the giant reed ash-concrete mix. This paper presents the experimental investigation carried out to study the effect of using giant reed ash to replace the sand in concrete mixes by 2.5, 5.0, 7.5, 10.0, and 12.5 %.

MATERIALS AND MIX DESIGN

Materials. The materials used in this study are locally available. Type I Portland cement was used in all types of concrete mixes. The chemical analysis of cement was carried out according to ASTM C114. The chemical components and physical properties of the cement are presented in Tables 1 and 2, respectively. The fine aggregate was natural sand of 4.75 mm maximum size and of desert origin obtained from the Al-Ukaider area in Iraq. Table 3 presents the physical properties of the sand. Table 4 show the sand gradation which was confirmed to ASTM C136. Natural crushed stone aggregate of maximum size 20 mm and bulk density of 1550 kg/m^3 was supplied from the Al-Nibaey region in Iraq.

Table 1. Chemical composition of cement

Compounds	**% (by weight)**
CaO	59.4
SiO_2	22.9
Al_2O_2	4.48
Fe_2O_3	5.83
SO_3	2.41
L.O.I	3.25
L.S.F	0.77
I.R	1.43
C_3S	62.0
C_2S	10.7
C_3A,	9.30
C_4AF	3.50

Twelve kilograms of giant reed ash (GRA) was used in this study as fine aggregate. The giant reed ash was prepared by air-drying the freshly collected stalks of giant reed for 3 days, followed by grinding the dried stalks into small pieces, and then burn the air-dried giant reed pieces in a furnace at 850ºC in order to obtain the giant reed ash.

The giant reed was originally collected from local marshes areas in Al Kut city, Iraq as undesirable wasted species of no economic value causing several environmental problems including fires. Samples of the air-dried giant reed stalks and giant reed ash are shown in Figs. 1 and 2, respectively. The appropriate chemical composition of the fresh giant reed is 21.1% lignin, 31.1% cellulose, 30.3% hemicellulose, and 12.1% extractives (Wang et al., 2009). The major mineral elemental composition of giant reed consists of 6850, 20, 2090, and 110 mg/kg of K, Mg, Ca, and Na, respectively as identified in this study. Tables 1 & 2 present the physical properties and the gradation of giant reed, respectively.

Table 2. Physical properties of cement

Properties		**Value**
Fineness		268
Safety - Elongation		0.18
Compressive strength, (Mpa)	3 days	16.7
	7 days	25.1
Setting Time, (Min)	Initial	77.0
	Final	272

Table 3. Physical properties of sand and GRA

Properties	**Value**	
	Sand	**GRA**
Finesse modulus	2.31	-
Absorption (%)	2.90	4.85
Max size (mm)	4.75	1.50
Density (kg/m^3)	1700	1275
Specific gravity	2.59	1.95

Table 4. Gradation of fine aggregate

Sieve size, (mm)	**Accumulated % passing**	
	Sand	**GRA**
4.75	91.05	100
2.36	88.15	100
1.18	82.30	90
0.60	67.25	85
0.30	21.17	75
0.15	1.25	50

Figure 1. Freshly collected giant reed

Figure 2. Giant reed ash (GRA)

Experimental procedure. For mixture proportioning, two types of concrete mixes were prepared for this study; the reference mixes (G0) which consisted of 739 kg/m^3 sand, 928 kg/m^3 gravel, 415 kg/m^3 cement and a W/C ratio of 0.55 for each reference mix. The other type of concrete mixes G1, G2, G3, G4, and G5 were made of 2.5, 5.0, 7.5, 10.0, and 12.5%, respectively as partial replacement of sand with similar amounts of cement, gravel, and water-cement ratio as in the reference mixes. All mixes were cured for 7, 14, and 28 days. Table 5 illustrates the details of the mixture proportioning

Table 5. Mixture proportioning

Symbols	Cement (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	GRA (kg/m^3)	Water/ Cement ratio
G0	415	928	739.0	-	0.55
G1	415	928	720.5	18.50	0.55
G2	415	928	703.0	36.00	0.55
G3	415	928	683.5	55.43	0.55
G4	415	928	665.1	73.89	0.55
G5	415	928	646.6	92.37	0.55

Preparation of specimen. Seventy four cubes of concrete of 150 × 150 × 150 mm were molded for compressive strength and dry density tests, whereby 58 prisms of size 70 × 70 × 38 mm were cast for flexural strength and toughness tests. The casting, compaction and curing were accomplished according to B.S.1881, part 7 and B.S.1881, part 6. The slump test was fulfilled according to B.S.1881, part 2. The Dry density values were measured for the cubes taken from curing water basin just prior to compression strength test according to B.S.1881, part 5. For the compression strength test, concrete cubes were prepared according to B.S.1881, part 7. Forney machine was used for the compression test. The cubes were tested immediately after taken out of water while they were still wet. The average of compression strength value for 4 cubes was recorded at each testing age. For the flexural strength and toughness, the prisms were prepared according to ASTM C192. A 10 KN proving ring capacity and 0.01 mm dial gage precision was used for those tests. The flexural strength test was carried out according to ASTM C293. The toughness indices were implemented according to ASTM C1018.
Each test result is given as an average of 4 values at each curing age. However, the standard deviations are not shown due to their small values relative to the scale of the plots.

RESULTS AND DISCUSSION

Slump test. The results of the slump tests for GRA-concrete mixes are presented in Fig. 3. These results indicate that the slump is prone to decrease sharply with increasing the giant reed ash (GRA) content. This decline in the slump values can be related to the poor geometry of the waste giant, which results in less fluidity of the mixes as well as the reduction of fineness modulus. Also, increasing the GRA percentage decrease the water content available in concrete mixture causing lower slump value. In spite of the decline in the slump values, the GRA modified concrete mixes were considered workable.

Dry density test. The dry density tests for GRA-concrete mixes G1, G2, G3, G4, and G5 are given in Fig. 4. The dry density values at each curing age tend to decrease with increasing the GRA content in each concrete mix. However, the dry density values tend to increase with time for G1, G2, G3, and G4 concrete mixes. It is clear that at 28 days curing age, the lowest dry density (2270 kg/m^3) exceeds the range of the dry density for structural lightweight concrete. This reduction could be attributed to the fact that the density of giant is lower than that of sand by 75%. The tendency of dry density for concrete mix (G5) differed from the other mixes. The decrease of dry densities with time for GRA-concrete mix G5 could be attributed to the assumption that flocculated and agglomerated cement and giant ash particles occupying larger spaces leading to a corresponding decrease in dry density.

Compressive strength test. The results of the compressive strength tests for the GRA-concrete mixes are shown in Fig. 5. According to the test results, the optimum 28-day compressive strength value of 39.05 MPa was obtained for the concrete mix made of 7.5% giant reed ash, which represents an increase in the compressive strength of up to 6.5% compared to the control or reference mix. The compressive strength increases with the increasing of the GRA content (G1, G2, and G3), and then after that the compressive strength decreased with the increasing of waste giant (G4 and G5). By increasing the percentage GRA up to 7.5%, the results show a tendency for compressive strength values of waste giant concrete mixes to increase below the plain mixes at each curing age.

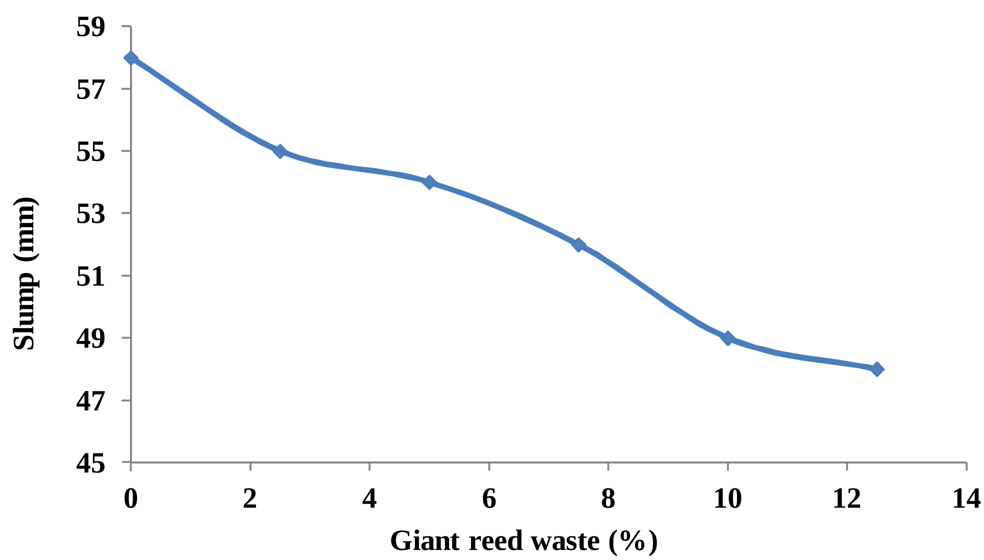

Figure 3. Workability of GRA- concrete mixes

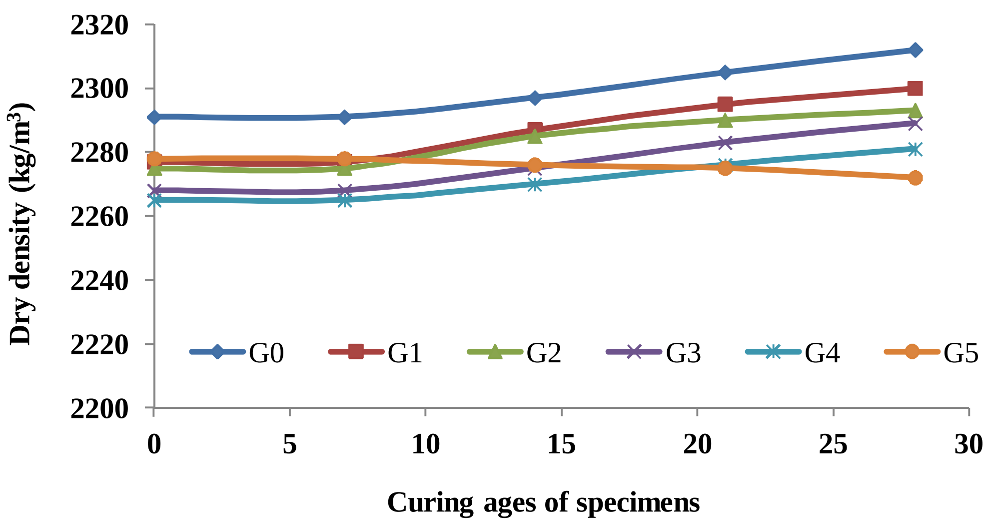

Figure 4. Dry densities of GRA- concrete mixes

This trend could be attributed to the pozzolanic action of giant reed ash, and the increasing in adhesive strength between the surface of the GRA and the cement paste. Also, at early age giant reed ash reacts slowly with calcium hydroxide liberated during hydration of cement. By increasing the GRA from 7.5% up to 12.5%, the results show a tendency for compressive strength values of GRA-concrete mixes to increase. However, by increasing the ratio of GRA up to 12.5% only, the compressive strength values decrease. This could be due to the fact that increasing the content of GRA in the concrete may hinder the water necessary for cement hydration from entering through the structure of the concrete specimens during the curing period.

Flexural strength test. The results of the flexural strength tests for the GRA- concrete mixes G1, G2, G3, G4, and G5 are illustrated in Fig. 6. According to the test results, the optimum 28-day flexural strength value of 5.45 MPa was obtained for the concrete mix made with GRA replaced sand by 7.5%, which represents an increase in the flexural strength of up to 6.7% compared to the control mix. The results show that the flexural strength of GRA-concrete mixes at each curing age is prone to decrease with the increase of the GRA ratio in these mixes up to 7.5% ratio, and then the flexural strength decreased with increasing the ratio of GRA up to 12.5%. This trend can be attributed to the decrease in adhesive strength between the surface of giant reed ash particles and the cement paste. Also, the repellent nature of giant reed ash may limit the hydration of cement.

Further investigation may be necessary to examine the compressive and flexural strength profiles for concrete mixes modified with GRA to replace sand by more than 12.5%.

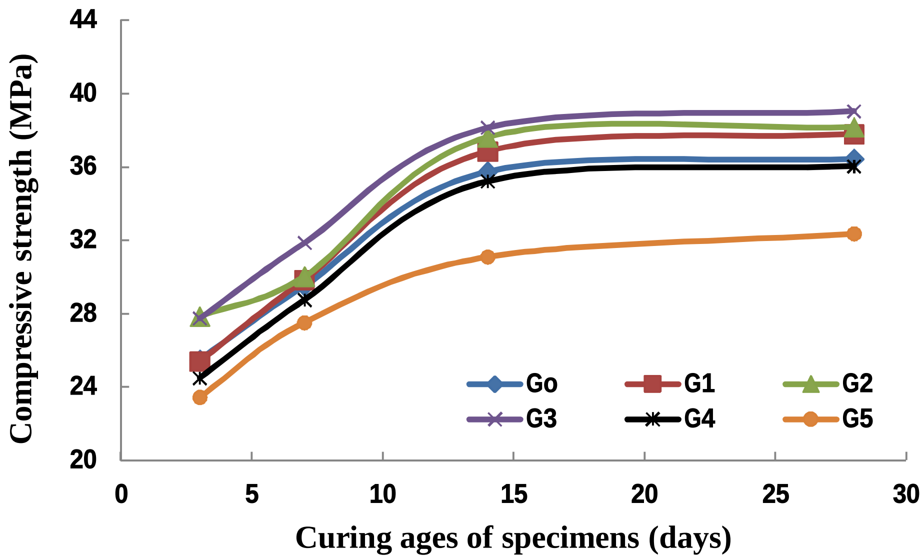

Figure 5. Compressive strength of GRA-concrete mixes

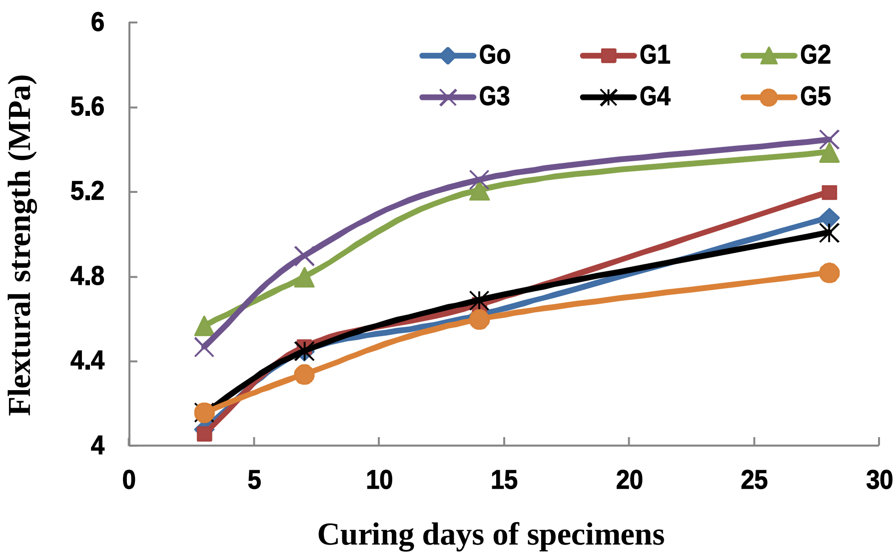

Figure 6. Flexural strength of GRA-concrete mixes

CONCLUSION

The main conclusions that can be drawn from this study are:

- This study intended to find effective promising approach to dispose the undesirable giant reed plants in concrete. The results presented in this paper show that further investigation may be considered regarding the application of crushed air-dried giant reed in concrete mixes and compare its effectiveness to the GRA.
- Replacement of sand in concrete mixes by 7.5% giant reed ash (GRA) was found to be the optimum ratio which produces the maximum values of compressive and flexural strengths.
- Using the giant reed ash (GRA) as a partial replacement for fine aggregate did not have any notable effect on the concrete color.
- The slump test values of GRA modified concrete decreased with increasing the giant reed ash (GRA) ratio up to 12.5%. In spite of this decline in the slump values, the GRA-concrete mixes were considered workable.
- The density of GRA-concrete mix decreased with the increase in giant reed ash content due to the low specific gravity of GRA compared to fine aggregate.

REFERENCES

American Society for Testing and Materials, (1979). Standard test method for flexural strength of concrete (using simple beam with center-point loading), ASTM C293, Annual book of ASTM standards.

American Society for Testing and Materials, (1985). Standard test method for flexural toughness and first crack strength of fiber-reinforced concrete (using bean with third-point loading), ASTM C1018, Annual book of ASTM standards.

American Society for Testing and Materials, (1988). Standard practice for making and curing concrete test specimens in laboratory. ASTM C192, Annual book of ASTM standards.

American Society for Testing and Materials, (1985). Standard chemical analysis of hydraulic cement. ASTM C 114, Annual Book of ASTM Standards.

American Society for Testing and Materials, (1984). Standard test method for sieve analysis of fine and coarse aggregates. ASTM C136, Annual Book of ASTM Standards.

Bell, G. P. (1993). "Biology and growth of giant reed (*Arundo donax*)". *Arundo donax workshop proceedings*. California Non-native Pest Plant Council and Team Arundo, Santa Ana, CA, U.S.A.

British Standard Institution, (1952). Methods of testing concrete, B.S.1881, BSI, London.

British Standard Institution, (2002).Concrete. Complementary British Standard to BS EN 206-1.Berkshire: British Standard Institution.

Bentz, D.P., Hanson, A.S., Guynn, J.M. (2011). “Optimization of cement and fly ash particle sizes to produce sustainable concretes.” *Cement & Concrete Composites*, 33, 824-831.

Dudley, T.L. Bossard, C.C., Randal, J.M., Hosovsky, M.C. (2000). Invasive Plants of California Wildlands, Univ. of California Press, Berkeley, Calif. Arundo donax., 53–58.

Frandsen, P., Jackson, N. (1994). “The impact of Arundo donax on flood control and endangered species.” *Arundo donax workshop proceedings*, 13-16.

Fuller, T. C., Barbe, G. D. (1985). “The Bradley method of eliminating exotic plants from natural reserves.” *Fremontia*, 13, 24-26.

Herrera, A.M., Dudley, T.L. (2003). “Reduction of riparian arthropod abundance and diversity as a consequence of giant reed (*Arundo donax*) invasion.” *Biological Invasions*, 5, 167–177.

Ismail, Z.Z., Al-Hashmi, E.A. (2008). “Use of waste plastic in concrete mixture as aggregate replacement.” *Waste Management*, 28, 2041-2047.

Ismail, Z.Z., Al-Hashmi, E.A. (2009). “Recycling of waste glass as a partial replacement for fine aggregate in concrete.” *Waste Managemen*t, 29, 655-659.

Malaiškiene˙, J. Vaicˇiene˙, M., Zˇurauskiene, R. (2011). “Effectiveness of technogenic waste usage in products of building ceramics and expanded clay concrete.” *Construction and Building Materials*, 25, 3869-3877.

Wang, W., Yue, Q., Xu, X., Gao, B., Zhang, J., Li, Q., Xu, J. (2010). “Optimized conditions in preparation of giant reed quaternary amino anion exchanger for phosphate removal.” *Chemical Engineering Journal*. 157, 161–167