VOL. 7, NO. 9, SEPTEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MACHINE CRUSHED ANIMAL BONES AS PARTIAL REPLACEMENT OF COARSE AGGREGATES IN LIGHTWEIGHT CONCRETE

Javed Ahmad Bhat, Reyaz Ahmad Qasab and A. R. Dar
Department of Civil Engineering, National Institute of Technology, Srinagar, Kashmir, India
E-Mail: bhat_javed@yahoo.com

ABSTRACT

An exploratory study on the suitability of the machine crushed animal bones as partial or full replacement for normal coarse aggregates in concrete works has been carried out. Physical and mechanical properties of machine crushed animal bones and locally available normal aggregate have been determined and compared. A large number of concrete cubes of size 150×150×50 mm with different percentages by weight of normal aggregate to crushed animal bones as coarse aggregate in the order 100:0, 75:25, 65:35, 50:50, 25:75 and 0:100 were cast, tested and their physical and mechanical properties were determined. Compressive strength tests showed that approximately 50% of the crushed animal bones in replacement for normal aggregate were quite satisfactory with no compromise in compressive strength requirements for concrete mix ratio 1:1.5:3. The study has been carried out at 25%, 35%, 50%, 75%, and 100% replacement levels of normal aggregate by crushed animal bone (CAB) aggregate by weight and a comparative study has been done between normal concrete and crushed animal bone (CAB) concrete.

Keywords: crushed animal bone, concrete, light weight aggregate, compressive strength, unit weight.

INTRODUCTION

Concrete, so commonly accepted in buildings, bridges and in numerous other structures, is taken for granted as massive and weighty construction material. Not necessarily so! A broad spectrum of lightweight concretes is being manufactured nowadays. Initially, Romans established durability of lightweight concrete by using natural aggregates from volcanic deposits. After the development of Portland cement in the early 1800s, though, it took the discovery and development of manufactured lightweight aggregates in the early 1900s to bring structural lightweight concrete to full maturity. The primary aim of lightweight concrete is to reduce the dead weight of concrete to be used in a structure which then allows a designer to reduce the size of structural elements (columns/beams) and size of foundation as well. Lightweight material has high potential to reduce the seismic mass of the structure and thereby reduce the level of seismic forces acting on a structure.

Many experimental works have been carried out to improve the properties of the concrete by adding new materials; the materials may be natural materials or recycle materials or synthetic materials. The additional (new) material can be replacing the aggregate or cement or just as additive, however, many of these additional materials are used as aggregate for the production of lightweight concrete. The main natural lightweight aggregates (LWAs) are diatomite, pumice, scoria, volcanic cinders and tuff (Neville and Brooks, 2008) and the most popular way of achieving light weight concrete (LWC) production is by using LWA (Polat *et al*., 2010). A lot of research has been conducted on the structural performance of lightweight aggregate concrete; these are mostly confined to naturally occurring aggregates, manufactured aggregates, and aggregates from industrial by-products. Numerous achievements have been made in this regard and the subject is attracting attention due to its functional benefit of waste reusability and sustainable development. Reduction in construction costs and the ability to produce light-weight structures are added advantages. In recent years, many research works on the use of palm kernel shells as lightweight aggregate (LWA) to produce lightweight aggregate concrete (LWAC) have been carried out (Abdullah, 1984, 1996; Okafor, 1988; Falad, 1992; Basri *et al*., 1999; Mannan and Ganapathy, 2001; Mannan and Ganapathy, 2004; Teo *et al*., 2007).

Semi-lightweight concretes produced by using volcanic slag as coarse aggregate were also investigated and it was found that the volcanic slag can be safely used in the production of semi-lightweight concrete (Topcu, 1997). Combination of coconut shell and grained palm kernel shell were also used as lightweight aggregate in concrete thereby reduces the cost of concrete as well (Tukiman and Sabarudin, 2009). Other types of lightweight aggregates include pumice, scoria, expanded shale, expanded clay, expanded slate, fly ash, blast furnace slag and crushed animal bone. In the present study coarse aggregate has been partially replaced by crushed bones to produce desired light weight concrete.

As reported above extensive work has been carried out on various natural as well as artificial lightweight aggregates to produce lightweight aggregate concrete, no work is reported to have been done on crushed animal bones as lightweight aggregates in concrete. As far as bone is concerned, it is a very light and hard material composed of a cellular component and an extracellular matrix. Besides being light and hard, bone does not deteriorate easily. The remains of animal (bones) are dug out even after hundreds of years [Archeological Survey of India (ASI)] providing a vital clue that the decaying period of bones is good enough to be used in concrete works.

In the state of J and K alone, more than 80 thousand tons of waste animal bones are produced annually providing a scope for its small scale utilization in construction industry. Therefore, an effort has been made to utilize these bones (crushed) to study the effect of animal bones on the production of lightweight concrete.

EXPERIMENTS AND RESULTS

For the purpose of the current investigation, animal bones were crushed to produce aggregate shapes designated here as crushed animal bone (CAB) aggregate. These CAB aggregate were used as partial to full replacement of conventional aggregates in concrete specimen. Nominal concrete mix M20 (1: 1.5: 3; cement: sand: aggregate), has been used with water/cement ratio of 0.45. Ordinary Portland Cement (OPC) of 43 Grade conforming to IS: 8112-1989, fine aggregate (natural sand obtained from river) conforming to Zone-II (IS: 383-1970), coarse aggregates (crushed stone aggregates, 10-20mm in size) and crushed animal bone (CAB) were other ingredients used in the concrete specimen for investigation.

Properties of crushed animal bone (CAB) aggregate

The CAB aggregate was machine crushed in the size range of 10-20mm and below. Typical shapes of the CAB aggregate are shown in Figure-1. The CAB aggregate is calcareous in nature and can bind easily with cement products. Being organic in nature, the properties of CAB aggregate highly differ from the conventional aggregates. The physical properties of CAB aggregate and normal aggregates used in the study are presented in Table-1 for comparison purposes. From this Table it is observed that bulk density of crushed animal bones CAB aggregates have a unit weight of 7.70-8.25 kN/m^3 and this is approximately 35% lighter compared to the conventional aggregates (15.70-22.00 kN/m^3). Aggregates having unit weights (of less than) 12.00 kN/m^3 are classified as lightweight aggregates (Owens, 1993). Further, it is observed that water absorption value is higher as compared to normal aggregate. In general, most of the lightweight aggregates have higher water absorption values compared to that of conventional aggregates. Light weight aggregate with higher water absorptions were recorded for pumice aggregates (volcanic rock) which have a water absorption value of about 37% (Hossain, 2004). However, the high water absorption of CAB aggregate can be beneficial to the resulting hardened concrete. It has been reported that lightweight concrete with porous aggregates (high water absorption) are less sensitive to poor curing as compared to normal weight concrete especially in the early ages due to the internal water stored by the porous lightweight aggregate (Al-Khaiat and Haque, 1998).

Table-1. Physical properties of aggregates.

Properties	CAB aggregate	Normal aggregate
Maximum aggregate size, mm	20.0	20.0
Bulk density, Kg/m^3	822	1510
Specific gravity (SSD)	1.61	2.65
Fineness modulus	6.66	6.59
Aggregate crushing value (%)	22.0	16.08
24-hour water absorption (%)	4.00	0.20

The particle size distribution of CAB aggregate and normal aggregates is shown in Figure-2 indicating well graded particle size distribution having all types of sizes of aggregate in both types of aggregates. The mechanical properties of bones are presented in Table-2 and a typical stress-strain curve resulting from a tensile test conducted on a bone specimen is shown in Figure-3 for reference, (Martin *et al*., 1998). The behavior of bone in uni-axial tension in comparison to other common materials is shown in Figure-4.

From Table-1 it is further observed that the crushing value of CAB aggregate is higher than normal aggregate indicating poor strength of CAB aggregate as compared to normal aggregate.

Figure-1. Shapes of CAB aggregate.

VOL. 7, NO. 9, SEPTEMBER 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

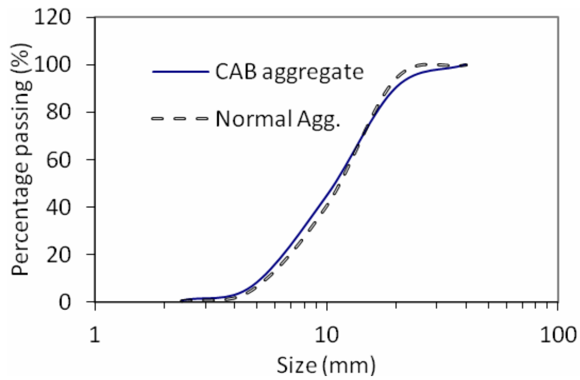
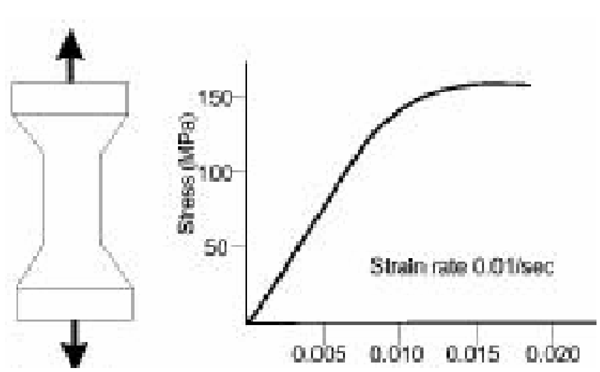


Figure-2. Particle size distribution of CAB aggregate.

Table-2. An overview (or representative average) of cortical bone properties for human and cow martin *et al*. (1998):

Property	Bovine (Cow) value
Elastic modulus transverse	20.4 GPa
Elastic modulus long	11.7 GPa
Shear modulus	4.1 GPa
Tensile yield stress long	141 MPa
Tensile ultimate stress long	145 MPa
Tensile ultimate stress trans	50 MPa
Compressive yield stress long	196 MPa
Compressive yield stress trans	150 MPa
Compressive ultimate stress long	137 MPa
Compressive ultimate stress trans	178 MPa
Tensile ultimate strain	0.67-0.72%
Compressive ultimate strain	2.5-5.2%



Specimen Strain

Figure-3. Illustration of a bone test specimen and a stress-strain curve resulting from a tensile test.

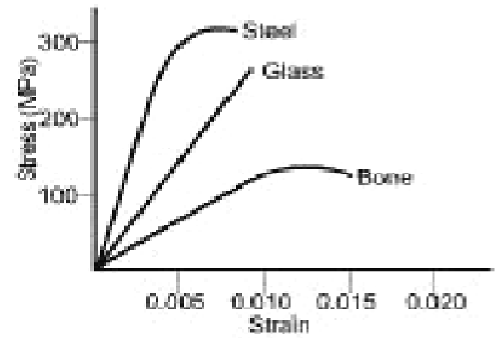


Figure-4. Behavior of bone in uni-axial tension compared to other common materials.

Properties of light weight concrete with crushed animal bones

Concrete specimens were prepared replacing normal aggregate by CAB aggregate as coarse aggregate (in percent by weight) in proportion of 100: 0 [coarse aggregate (100%): CAB aggregate (0%)]; 75: 25 [coarse aggregate (75%): CAB aggregate (25%) i.e., 25% of normal aggregates is replaced by CAB aggregate]; 65: 35 (i.e., 35% of normal aggregates is replaced by CAB aggregate), 50: 50 (i.e., 50% of normal aggregates is replaced by CAB aggregate), 25: 75 (i.e., 75% of normal aggregates is replaced by CAB aggregate) and 0: 100 (i.e., 100% of normal aggregates is replaced by CAB aggregate). Thus the replacement of normal aggregate by CAB aggregate is in the range from 0% to 100%.

Six different mixes (1:1.5:3) were prepared one each for 0%, 25%, 35%, 50%, 75% and 100% replacement levels of normal aggregates by CAB aggregate for casting various specimens viz. cubes (150mm x 150mm x 150mm), for computation of compressive strength and unit weights of these concretes. For the purpose of computing above stated properties, a total of 144 cubes were cast, properly cured in water and tested at the age of 7 and 28 days. Since the CAB aggregate has a water absorption value of 4% as compared to 0.2% for that of the normal aggregate, there was every apprehension that the CAB aggregate will absorb more water from the mix during mixing operation, thus affecting the workability, water/cement ratio and hence the strength as well. In order to avoid this problem, the CAB aggregate were pre-wetted (soaked) for 24 hours and surface dried.

Workability

As expected, the workability of CAB concrete reduces as the percentage of CAB aggregates increases. This can be attributed to the fact that since the normal aggregates are denser (heavier) than CAB aggregates and the replacement is by weight, the specific surface area increases as the CAB aggregate content is increased. Since the CAB aggregates are very light and do not settle (sink) easily, slump test is not a true indicator of workability for CAB concrete. Therefore, workability has been determined by performing compaction factor test.

The reduction in workability of concrete batches for different percentages of CAB aggregates using compaction factor test has been estimated and is shown in Table-3. It is observed that there is a reduction in compaction factor upto 9%, however the values of compaction factor still falls in medium workability range (IS: 456-2002). The workability is found to decrease with the increase in the replacement level of the normal coarse aggregates with the CAB aggregates. This can be attributed to the fact that since the normal aggregates are denser than CAB aggregates and the replacement is by weight, the specific surface area increases as the CAB aggregate content is increased. Thus, increase in the specific surface area due to lightness of CAB aggregates and greater amount of water needed for the mix ingredients to get closer packing, results in decrease in workability of mix.

Table-3. Reduction in workability of CAB concrete for different percentages of CAB aggregates.

CAB aggregate used (%)	0	25	35	50	75	100
Compaction factor	0.896	0.885	0.860	0.847	0.834	0.815
Reduction in compaction factor (%)	-	1.2	4.0	5.5	6.9	9.0

Compressive strength

The compressive strength of concrete cubes made with and without CAB aggregates has been determined at 7, 14, 21, and 28 days. The average compressive strength (cube strength) results are shown in Table-4. From these results it is observed that compressive strength decreases as the CAB aggregate content increases (as percentage of normal aggregates decrease). As expected, the compressive strength is maximum for specimen with 100% normal aggregate (i.e., no replacement of normal aggregates by CAB aggregates) and minimum when CAB aggregate content is 100%. It is further observed that the minimum 28-day cube strength value of 20 N/mm^2 (M-20) as expected for nominal concrete mix 1:1.5:3 could still be achieved with approximately 50% CAB aggregate inclusion.

Though the compressive strength achieved by CAB concrete is low, however, lower compressive strengths have been reported for light weight aggregate concretes. The compressive strengths of concrete cube specimens with 50% and 100% periwinkle shells for 1:1.5:3 ratio have been found to be 17 N/mm^2 and 8 N/mm^2 respectively (Adewuyi and Adegoke, 2008) and the unit weight achieved was 16.05kN/m^3 for 100% inclusion of periwinkle shells.

Compressive strength can be improved by using silica fume (SF). The SF has been successfully used in the past to improve the bond between the Palm Kernel Shells (PKS) and the cement matrix that could ultimately increase the strength properties of the Palm Kernel Shell Concrete (PKSC). The extremely fine SF particles react with the liberated calcium hydroxide to produce calcium silicate and aluminate hydrates. These both increase the strength and reduce the permeability by densifying the matrix of the concrete (Robert *et al*., 2003; Neville, 1996). Thus the zone between aggregate and cement paste interface, which is called the zone of weakness, could be strengthened by the use of SF. It has been observed that the strength of PKSC without silica fume generally lies in the range of 15-25MPa (Teo *et al*., 2006). However, with the addition of 10% of silica fume, the strength of 36.5MPa has been reported showing an increase of about 39% in compressive strength **(**Johnson Alengaram *et al*., 2008). Therefore, silica fume can be used in CAB concrete to increase its strength which makes it acceptable for structural members, as some of the codes of practice stipulate minimum strength of lightweight concrete (LWC) as 15MPa (FIP Manual, 1983).

Table-4. Average compressive strength of concrete at 7days and 28 days of testing.

%age of CAB in concrete	**Compressive strength at 7 days** (N/mm^2)	**Compressive strength at 28 days** (N/mm^2)
0	18.93	**28.25**
25	17.63	26.40
35	16.07	24.36
50	12.38	19.20
75	10.02	16.17
100	8.05	12.37

Unit weight

For structural applications of lightweight concrete, the density is often more important than the strength (Rossignolo *et al*., 2003). The reduction in unit weights of the CAB concrete for various percentages of CAB aggregates and normal aggregate at the age of 28 days is shown in Table-5. As can be observed from this Table that the average unit weights corresponding to 50%, 75%, and 100% of CAB aggregate inclusion in concrete are 19.60 KN/m^3, 17.65 KN/m^3, and 16.55 KN/m^3 respectively for nominal concrete mix 1:1.5:3. These fall within the range of lightweight concrete, as lightweight concrete is defined as the concrete whose dry density varies from 14 kN/m^3 to 20kN/m^3 compared with that of 24 kN/m^3 for normal-weight concrete (NWC) (Chen and Liub, 2005).

Table-5. Variation in unit weight of hardened concrete at 28 days age.

Percentage of CAB (%)	**Unit weight** (KN/m^3)	**% age reduction in unit weight**
0	2415	0.00
25	2273	6.00
35	2145	11.00
50	1960	19.00
75	1765	27.00
100	1655	31.50

CONCLUSIONS

On the basis of results produced in this study it is concluded that:

- Lightweight concrete using CAB aggregate can be achieved by replacing normal aggregate by CAB aggregate approximately 50% or more.
- The average unit weights corresponding to 50%, 75%, and 100% of CAB aggregate inclusion in concrete are 19.60 KN/m^3, 17.65 KN/m^3, and 16.55 KN/m^3 respectively, for nominal concrete mix 1:1.5:3.
- Compressive strength of CAB concrete (lightweight) is low as compared to normal concrete; however, it can be improved by using silica fume (SF).
- Besides achieving economy in construction, by reducing the weight of the structure, the catastrophic earthquake failures caused due to inertia forces (earthquake forces are proportional to the weight of the structure) that influence the structures can also be ultimately reduced.

REFERENCES

Abdullah A.A.A. 1984. Basic Strength Properties of Lightweight Concrete Using Agricultural Wastes as Aggregates. Proceedings of International Conference on Low-cost Housing for Developing Countries, Roorkee, India.

Adewuyi A.P. and Adegoke T. 2008. Exploratory study of periwinkle shells as coarse aggregates in concrete works. Asian Research Publishing Network (ARPN). 3(6): 1-5.

Al-Khaiat H and Haque M.N. 1998. Effect of internal curing on early strength and physical properties of a lightweight concrete. Cem. Con. Res. 28(6): 859-866.

Basri H.B., Mannan M.A. and Zain M.F.M. 1999. Concrete using waste oil palm shells as aggregate. Cem. Con. Res. 29: 619-622.

Chen B. and Liub J. 2005. Contribution of hybrid fibers on the properties of the high-strength lightweight concrete having good workability. Cem. Con. Res. 35: 913-917.

1983. F.I.P Manual of Lightweight Aggregate Concrete. 2nd ed. Surry University Press, Glasgow and London.

Falade F. 1992. The use of palm kernel shells as coarse aggregate in concrete. Journal of Housing Science. 16(3): 213-219.

Indian Standards. 1970. IS: 383, Specification for Coarse and fine aggregates from Natural sources for concrete. Bureau of Indian standards, New Delhi, India.

Indian Standards. 1989. IS: 8112, 43. grade ordinary Portland, Cement-specification (first revision). Bureau of Indian standards, New Delhi, India.

Indian Standards. 2000. IS: 456. Plain and reinforced concrete-Code of practice (fourth revision). Bureau of Indian standards, New Delhi, India.

Johnson U.A., Jumaat M.Z. and Mahmud H. 2008. Influence of cementitious materials and aggregate content on compressive strength of palm kernel shell concrete. J. Appl. Sci. 8: 3207-3213.

Jumaat M.Z., Alengaram U.J. and Mahmud H. 2009. Shear Strength of Oil Palm Shell Foamed Concrete Beams. Mater. Design. 30: 2227-2236.

Mahmud H., Jumaat M.Z. and Alengaram U.J. 2009. Influence of sand/cement ratio on mechanical properties of palm kernel shell concrete. J. Appl. Sci. 9: 1764-1769.

Mannan M.A. and Ganapathy C. 2001. Mix design for oil palm shell concrete. Cem. Con. Res. 31: 1323-1325.

Mannan M.A. and Ganapathy C. 2004. Concrete from an agricultural waste oil palm shell (OPS). Build. Environ. 39: 441-448.

Neville A.M. and Brooks J.J. 2008. Concrete technology. Malaysia: Prentice Hall.

Neville A.M. 1996. Properties of concrete. Longman Group Limited, London, UK.

Okafor F.O. 1988. Palm Kernel Shell as a Lightweight Aggregate for Concrete. Cem. Con. Res. 18: 901-910.

Olanipekun E.A., Olusola K.O. and Ata O. 2006. A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. Buil. Environ. 41: 297-301.

Owens P.L. 1993. Lightweight aggregates for structural concrete, Structural Lightweight aggregate concrete. J.L. Clarke (Ed.). Blackie Academic and Professional, London. pp. 1-18.

Polat R., Demirbo_A.R., Karakoç M.B. and Türkmen I. 2010. The influence of lightweight aggregate on the physico-mechanical properties of concrete exposed to freeze–thaw cycles. Cold Reg. Sci. Tech. 60: 51-56.

Robert L., Lindon S., Peter W. and Ray R. 2003. Cementitious additions. In: John N, Ban SC (Eds.). Advanced Concrete Technology. Elsevier publications, Amsterdam.

Rossignolo J.A., Agnesini M.V.C. and Morais J.A. 2003. Properties of high performance LWAC for precast structures with Brazilian lightweight aggregates. Cem. Con. Compo. 25: 77-82.

Teo D.C.L., Mannan M.A. and Kurian V.J. 2006. Structural Concrete Using Oil Palm Shell (OPS) as Lightweight Aggregate. Turk. J. Eng. Env. Sci. 30: 251-257.

Teo D.C.L., Mannan M.A., Kurian V.J. and Ganapathy C. 2007. Lightweight concrete made from oil palm shell (OPS): Structural bond and durability properties. Buil. Environ. 42: 2614-2621.

Topcu I.B. 1997. Semi-lightweight concretes produced by volcanic slags, Cem. Concr. Res. 27(1): 15- 21.

Tukiman S.A.B. and Sabarudin S.B. 2009. Investigate the combination of coconut shell and grained Palm kernel to replace aggregate in concrete: A technical Review, National Conference on Postgraduate Research (NCON-PGR), Malaysia. pp. 49-58.