ABSTRACT

Foamed concrete is a lightweight material with self-compacting rheological properties. Conventionally, it is produced from mixture of cement, fine aggregates (dredged sand) and mechanically entrained foam. Research findings have shown that the foam degenerates to create evenly distributed macro and micro air pores after 45 minutes; also, that other fine aggregates could be used as partial replacement of the dredged sand. In this respect, it has been established that laterite which is usually available near project sites and less expensive to procure is suitable as partial replacement of dredged sand in concrete. The particle size distribution of dredged sand contains inter-particle voids that contribute to the formation of macro air pores. These macro pores are defects that reduce structural properties of foamed concrete. In addition, non-application of foamed concrete made with available local materials in developing countries is due to dearth of information on its structural properties and the structural strengths of elements made with it. Thus, the application of laterite as partial replacement of dredged sand in foamed concrete to reduce macro pores with minimal impact on the rheological properties was examined. This study consists of two parts namely, preliminary and main investigations. During the preliminary investigation, the effects of replacing dredged sand with laterite on the rheological property (measured as spread diameter) and compressive strength of cube specimens at 28th day were examined. The variables were curing periods, methods of curing and proportions of laterite (0-100 % replacement of dredged sand by weight at interval of 10 %). In the main experiment, the structural properties of foamed concrete made with laterite between 0 and 25 % and the strengths of reinforced concrete beams made with the specimens were examined. Also, three curing methods namely; air, water, and initial curing in water for seven days before exposure to air curing for the remaining curing days were used. The results obtained at the preliminary stage showed that foamed concrete samples with laterite between 0 and 25 % as partial replacement of dredged sand satisfied flow consistency requirement and self-compacting rheological criterion: the spread diameters obtained which are between 532 mm and 642 mm are according to established specifications. The compressive strength of foamed concrete at 28th day increased with increases in proportions of laterite for specimens cured in all curing media. These results formed the basis for the main investigation using laterite in the proportions of 0, 5, 10, 15, 20 and 25 %. The results obtained from the main investigation, showed that specimens made with 25 % laterite content and cured initially in water for seven days before exposure to air curing developed the maximum 28th day structural properties: compressive strength (17.2 N/mm^2), split tensile strength (2.38 N/mm^2) and modulus of rupture (3.72 N/mm^2). These structural properties are greater than the minimum values recommended in ACI 213R (2014) for structural lightweight concrete. Therefore, the foamed laterized concrete with laterite as partial replacement of dredged sand between 0% and 25% in this investigation fit properly into the range of specifications for lightweight structural concrete and thus has the potential of application in such areas as load bearing walls, short span beams and slabs, low volume drain and infill in ribbed floor system. The differences in cost benefit analysis between 0% foamed laterized concrete and specimens with 5, 10, 15, 20 and 25 % laterite were 1.75, 3.5 110, 111 and 113 % respectively. These values justify the application of laterite as partial replacement of sand in foamed concrete production but with an optimum value of 25 % partial replacement of dredged sand with laterite.

Keywords: Foamed concrete, Laterite, Rheology, Structural properties

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τ = Shear stress (N/m^2)

γ = Shear rate (s^{-1})

τ_0 = yield stress (N/m^2)

η = Plastic viscosity (Ns/mm^2)

S = Slump (mm)

ρ = Density (kg/m^3)

g = Acceleration due to gravity (m/s^2)

H_0 = Initial (un-slumped) height (mm)

R = Radius of spread (mm)

V_s = Volume of sample (m^3)

r_1 = The smaller radius of the truncated cone (mm)

r_2 = The greater radius of the truncated cone (mm)

h_c = Height of truncated cone (mm)

Q = Rate of flow (m^3/s)

P = Pressure gradient driving the flow (km/s^2)

p = Minimum pressure at which flow begins (N/m^2)

L_f = Flow length (mm)

T = Torque (N.m)

G = Constant obtained by calibration with Newtonian fluids

K = Constant obtained by calibration with non- Newtonian fluids

N = Speed of the impeller (m/s)

f_{cu} = Compressive strength (N/mm^2)

f_0 = Compressive strength at zero porosity (N/mm^2)

P_0 = Porosity (%)

γ_d = Dry density (kg/m^3)

f_t = Split tensile strength (N/mm^2)

P_i = Maximum applied load by the testing machine (N)

l = Length of cylinder specimen (mm)

d_c = diameter of cylinder specimen (mm)

f_r = Modulus of rupture (N/mm^2)

b = Average width of the specimen (mm)

d_f = Average depth of the specimen at fracture (mm)

a = Distance between the line of fracture and the nearest support measured on the tension surface of the beam (mm)

$A_{s,min}$ = Minimum area of steel required (mm^2)

f_y = Characteristic strength of steel (N/mm^2)

$A_{s,max}$ = Maximum area of steel required (mm^2)

ρ_m = Maximum reinforcement ratio

A_s = area of tensile steel

d = depth of tensile steel from top most compression fibre

h = overall depth of beam

ε_{cc} = compressive concrete strain

ε_{ct} = tensile concrete strain

ε_{st} = tensile steel strain

f_{cc} = compressive concrete stress

f_{ct} = tensile concrete stress

f_{st} = tensile steel stress

f = Bending stress at a distance y from neutral axis (N/mm^2)

M = Applied bending moment at section (kN.m)

I = Moment of inertial of cross section about neutral axis (cm^4)

y = distance from the neutral axis

F_{cc} = compressive force

F_{st} = tensile force

x = depth of neutral axis from top fibre

s = equivalent depth of neutral axis from top fibre

z = lever arm

M_u = moment capacity of concrete beams

V = shear force at ultimate load

v = shear stress

v_c = ultimate shear stress in concrete

f_{yv} = characteristic tensile strength of link reinforcement

s_v = spacing of links along the member

A_{sv} = cross-sectional area of shear reinforcement in the form of links

D = Plastic density of foamed concrete (kg/m^3)

D_o = Dry density of foamed concrete at 28th day (kg/m^3)

D_B = Density of base mix (mortar) (kg/m^3)

S_D = Spread diameter (mm)

ϕ = Proportion of laterite (%)

w/c = water/cement ratio

C = Quantity of cement in the mix (kg)

W_f = Quantity of foam (kg)

W_w = Quantity of Water (kg)

F = Quantity of Fine aggregate (kg)

V_f = Volume of foam (m^3)

$A_{s,prov}$ = Area of steel provided (mm^2)

b_f	=	net width of hydrate
d_h	=	Net depth of hydrate
d_p	=	average diameter of air entrained pores
C_p	=	Total cost of product per cubic metre
R_c,	=	Unit rates of cement
R_f,	=	Unit rate of fine aggregates
R_w,	=	Unit rate of water
R_{ch}	=	Unite rate of foam concentrate
C_l	=	labour cost