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Physical properties of low density aircrete products

ABSTRACT: Currently in the UK, aircrete, also known as Autoclaved Aerated Concrete, masonry units are usually produced with a minimum declared compressive strength of 2.9 N/mm^2 (measured to EN 772-1) and a minimum density of 400 kg/m^3. However, newly introduced European Standards allow the use of lower strength and with this it is possible to produce lower density products, such as low-density aircrete with a minimum declared compressive strength of 2.0 N/mm^2 and a density of 350 kg/m^3. This paper provides details of an extensive investigation to assess key physical properties such as moisture properties, freeze/thaw resistance, thermal performance, combustibility and flanking sound performance of low-density aicrete products. The results show that key physical properties of low-density aircrete were comparable to conventional aircrete products.

KEY WORDS: physical properties, low density aircrete

1. Introduction

Aircrete was first developed in Sweden in 1924 and first used in the UK in late 1950's as an alternative to building with timber (H+H, 2003). Currently, Aircrete is being used extensively by major house builders in the UK that Aircrete (mainly medium and high density) now accounts for a third of all concrete blocks with an approximately 30 million m^2 of Aircrete block sales annually (Construction Markets, 2000).

Aircrete is produced by mixing cementitious materials, cement and/or pulverised fuel ash (PFA), lime, sand, water and aluminium powder. The final process involves autoclaving for approximately 10 hours at high temperature and pressure (Mitsuda and Kiribayashi, 1992; Isu and Mitsuda, 1992 and Pospisil, 1992), hence, the material is also known as AAC (Autoclaved Aerated Concrete) commercially. The solid material part, which consists of the crystalline binder called Tobermorite by mineralogist, constituent bulk of the binder with grains of Quartz and some other minerals are found in minor amounts (Aircrete Bureau, 2003). It is the Tobermorite, which comprises of silicium dioxide, calcium oxide and water that provides the high compressive strength of Aircrete in spite consisting high proportion of pores, which is about 60 – 85% of air by volume. Therefore, opportunity exists to use the relatively higher porosity of Low Density Aircrete, which consists of 70 – 85% of air by volume, produced with sufficient strength and lower density (typically of 350 kg/m^3) for dwellings construction.

The lightweight porous structure and easily manhandled of Aircrete blocks, provides significant improvement in productivity, thus enhancing the efficiency of construction and cost effective, in line with Egan's report on 'Rethinking Construction' (Egan, 1998). Key physical properties of Low Density Aircrete with a declared compressive strength of 2.0 N/mm^2 (2.0N) and a density of 350 kg/m^3 were investigated and compared with the conventional Aircrete blocks with a declared compressive strength of 2.9 N/mm^2 (2.9N) and a density of 460 kg/m^3.

2. Test materials and experimental programme

Two types of Aircrete blocks, namely (a) Low Density Aircrete of 620 x 150 x 250 mm with a compressive strength of 2.0 N/mm^2 (2.0N) and a density of 350 kg/m^3 and (b) Aircrete of 440 x 150 x 215 mm with a compressive strength of 2.9 N/mm^2 (2.9N) and a density of 475 kg/m^3 were used. A series of experimental work was carried out in accordance with appropriate British Standard.

Table 1

KEY PHYSICAL PROPERTIES EXPERIMENTAL PROGRAMME.

Physical properties	Testing
Dimension	BS EN 772: Part 16: 2000
Density	BS EN 772: Part 13: 2000
Moisture content by mass	BS EN 772: Part 10:1999
Water absorption	BS EN 772: part 11: 2000
Water absorption transmission	BS EN ISO 12572: 2001
Moisture movement	BS EN 680: 1994
Freeze/thaw resistance	British Board of Agrément MOAT 12: 1977
Thermal performance	BS EN 12664: 2001 (verified by reference to BS EN 1745: 2002)
Combustibility	BS EN ISO 1182:2002 and BS EN ISO 1716: 2002
Sound performance	This was carried out at Acoustic Test Laboratory in accordance with Part E of Building Regulations

3. Test results and discussion

3.1. Dimensions

The average measured dimensions for both 2.0N and 2.9N Aircrete masonry units were impressively within 3.0 mm of the theoretical values, as shown in Table 2.

Table 2

AVERAGE DIMENSIONS AND DENSITY OF 2.0N AND 2.9N.

Aircrete	average values			
	length (mm)	width (mm)	height (mm)	density (kg/m^3)
2.0	619.8	149.8	249.8	352
2.9	439.7	149.8	214.8	477

3.2. Density

The average measured density for 2.0N and 2.9N Aircrete masonry units was 350 kg/m^3 and 475 kg/m^3 respectively, which is remarkably within 0.57% and 0.42% of the desired values, as summarised in Table 2.

3.3. Moisture properties

Four different test methods have been used to assess and examine the moisture properties of 2.0N and 2.9N Aircrete units. These include moisture content by mass, water absorption properties, water vapour transmission properties and moisture movement. The test results are summarised in Table 3.

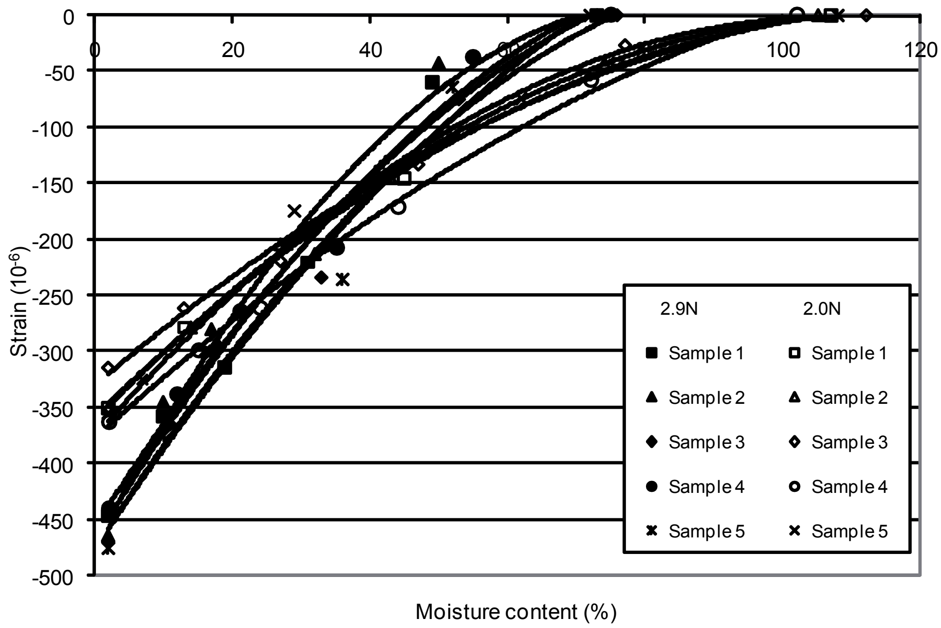

Fig. 1. Moisture movement for 2.0N and 2.9N Aircrete blocks.

The results show that the moisture contents of both types of Aircrete blocks are within the standard requirement of 6% – 30%. The coefficient of water absorption, $C_{w,s}$ was found to be greater for 2.9N Aircrete. This is as expected as the rate of absorption is determined by the dry density of the material, greater $C_{w,s}$ for the higher density materials (AAC, 1978 and Zhou et. al., 1992). Likewise, water vapour flow rate (G) and density of water vapour flow rate (g) was found to be greater for 2.9N Aircrete. The results suggest that the higher density material has a greater water vapour flow rate, hence, a higher density of water vapour flow rate. The results also show that higher density material has a greater drying shrinkage rate, as shown in Figure 1. However, the drying shrinkage rates of both Aircrete blocks are relatively very low, which equates to approximately 1 mm expansion for a 6 m wall.

Table 3

MOISTURE PROPERTIES TEST RESULTS.

Aircrete blocks (N/mm^2)	av. moisture content (% by mass)	coefficient of water absorption after long time exposure		water absorption transmission		av. drying shrinkage, e (x 10^{-6})
		Time (s)	$C_{w,s}$ [g / (m^2 · s$^{0.5}$)]	G (kg/s) (· 10^{-8})	G (kg/m^{2}s) (· 10^{-7})	
2.0	13.70	616800	32.5	2.24	2.89	300
		673320	28.1			
		3293220	21.6			
		522300	27.9			
		1274860	28.0			
		1383060	20.4			
2.9	13.60	699960	53.2	2.52	5.34	455
		1033200	41.8			
		1440900	36.3			
		1903800	32.0			
		1199460	37.9			
		2684220	41.2			

Table 4

COMPRESSIVE STRENGTH AND LOSS OF VOLUME OF 2.0N AIRCRETE BLOCKS AFTER FREEZE/THAW CYCLES.

freeze/thaw cycles	mean compressive strength(1) of remaining Aircrete (N/mm^2)	equivalent mean compressive strength(2) of Aircrete (N/mm^2)	change of strength (%)		loss of volume (%)
			(1)	(2)	
0	2.20	2.20	N/A	N/A	N/A
20	2.30	2.09	+ 4.5	- 6	1.5
40	2.20	1.74	+ 0.0	- 21	5.1
60	2.25	1.54	+ 2.3	- 30	6.4

3.4. Freeze/thaw resistance

The compressive strength and loss of volume of 2.0N Aircrete after 0, 20, 40 and 60 of freeze/thaw cycles are summarised in Table 4. The data show that the mean volume change (loss) was > 5% of the original samples volume after 60 cycles. The result exceeded the specified maximum limit. The majority of the volume loss occurred to the blocks load bearing surface that was immersed in the 25 mm water in the trays. Therefore, the compressive strength has been calculated (1) using the area of load bearing surface remaining of n number of freeze/thaw cycles and (2) using the original load bearing surface are prior to testing. A small increase was measured for the former (1) but a 30% decrease for the latter (2) and hence, exceeded the maximum specified loss in strength. The poor performance of 2.0N Aircrete subjected to freezing and thawing cycles could be attributed to the high volume of pores.

3.5. Thermal performance

The test results in determining the thermal conductivity (λ) of Aircrete blocks show that 2.0N Aircrete blocks has a lower λ value of 0.10 W/mK as compared to 2.9N Aircrete blocks, which has a λ value of 0.11 W/mK. The result is expected considering that the lower density of 2.0N Aircrete blocks has a higher proportion of pores than that of 2.9N Aircrete blocks. This thermally efficient of 2.0N Aircrete blocks offers great opportunities in providing an improved thermal insulation of dwelling; hence helping to meet the stringent thermal requirement of the UK Building Regulations Part L1 and J.

3.6. Combustibility

Table 5 and 6 summarises the fire resistance and gross calorific potential test results, respectively. The behaviour of the samples during the tests was observed and no difficulties were experienced. The 2.0N Aircrete blocks, in relation to its reaction to fire behaviour is classified as A1 in accordance with clause 10 and 11 of BS EN 13501: Part 1: 2002. This classification shows that 2.0N Aircrete blocks sufficiently meeting all likely fire resistance requirements, hence, enables them to be used for wall and floor applications. In reality, it is the performance of applied finishes, linings and cladding framework that need to be evaluated for their ability to limit fire spread.

3.7. Sound performance

The acoustic laboratory testing was done in accordance with Part E of the Building Regulations at Tarmac Topblock plant in Linford, Essex. The test was carried out on a wall structure which consists of internal separating and external flanking walls sitting on a permanent ground floor and a pitched roof. The thickness and density of blockwork was chosen to give approximately equivalent weight to a 300 mm thick wall in 350 kg/m^3 density blockwork.

Table 5

FIRE RESISTANCE TEST RESULTS OF 2.0N AIRCRETE BLOCKS.

test samples	1	2	3	4	5
Furnace thermocouple temperature rise, T_f (EC) (T_f maximum – T_f final)	1.2	2.1	2.1	1.7	3.1
Specimen centre thermocouple temperature rise, T_c (EC) (T_c maximum – T_c final)	0.2	0.5	0.4	0.3	0.1
Specimen surface thermocouple temperature rise, T_s (EC) (T_s maximum – T_s final)	0.9	1.2	1.2	1.1	1.9
Duration of sustained flaming (seconds)	NIL	NIL	NIL	NIL	NIL
Mass loss (%)	12.49	12.21	11.67	12.91	12.37

Table 6

CALORIFIC POTENTIAL TEST RESULTS OF 2.0N AIRCRETE BLOCKS.

test samples	sample weight (g)	calorific value (MJ/kg)	temperature rise (°C)	gross calorific value per unit mass (MJ/kg)	average gross calorific value per unit mass (MJ/kg)
1	0.6320	- 0.4863	1.6078	- 0.4863	-0.4320
2	0.5540	- 0.4523	2.0082	- 0.4523	
3	0.5672	- 0.3575	2.1786	- 0.3575	

The results show that solid low density Aircrete walls can perform to the requirements of Part E of the Building Regulations when used in conjunction with a recognised Aircrete separating wall. The performance of both the separating wall and the separating floor with low density flanking walls can achieve the required Part E performance.

4. Conclusions

It is evident that Aircrete, particularly Low Density Aircrete masonry has the potential to be use as modern construction material that offers excellent thermal and acoustic insulation, comparable moisture properties, lightweight and easily manhandled. Aircrete can combined with other fast build methods such as thin layer mortar masonry as well as prefabricated floor and wall unit, which will then greatly contribute towards an efficient construction solution, cost effective and improved buildability to meet today's housing requirements not only structurally sound, but also meet the necessary performance requirements relating to energy conservation and creating 'greener construction' in assisting the UK Government to tackle global warming. The application of Aircrete blocks as modern construction material will significantly alleviated the current problems in the UK construction industry, which is facing growing skills shortages with the repercussions of rising costs that can affect build quality, sustainability issues, completion times and costs and may even impact on health and safety.

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