

Effects of sand addition on production of lightweight aggregates from Tunisian smectite-rich clayey rocks

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Abstract

Smectite-rich claystone–marlstone samples from 12 outcrops located in the Southern Atlas domain of Tunisia were investigated with regard to manufacture of lightweight aggregates (LWAs). The clayey materials mainly consist of smectite, kaolinite and illite, together with quartz, calcite, dolomite and feldspars as accessory components. 10–12 mm pellets were prepared from wet paste and initially heated to 600 °C, 700 °C or 800 °C (depending on the raw material) for at least 2 h in order to avoid any explosion of the aggregate. The pellets were then subjected to a quick firing process at 1180 °C. The addition of 15% of quartz sand (<250 µm grain size) to the raw materials was found to improve some required pre-treatments and give better expansion properties to some of the aggregates. The addition of 1% used automobile oil to the clay and quartz sand mixtures caused the formation of more gas and a drop in bloating temperature. The obtained LWAs were characterized by physical properties such as apparent density, mechanical resistance, water absorption and expansion. The laboratory results were comparable to those of two commercial LWAs from France (Argidéc®) and Portugal (LECA®) and provide new openings for the utilization of Tunisian claystone in civil engineering work or in agricultural applications.

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1. Introduction

Lightweight aggregates (LWAs) are defined as natural or artificial materials, which are granular, porous and lightweight (Cougny, 1990). They can originate from different natural sources such as volcanic rocks (pumice, volcanic tuffs, Riley, 1951; De'Gennaro et al., 2004),

sedimentary rocks (clayey diatomite, Fragoulis et al., 2004), sedimentary and metamorphic rocks (claystones, slates, shales, Conley et al., 1948; Harris et al., 1962; Grosh and Hamlin, 1963; Das and Lebdetter, 1968; Dahab, 1980; Dahab and Champetier, 1983, 1984; Decler and Viaene, 1993) and from waste material or industrial by-products such as recycled flat glass and fly ash (Verma et al., 1998; Baykal and Doven, 2000; Ducman et al., 2002). LWAs have become a centre of interest due to their typical properties of good thermal and acoustic insulation, and good fire resistance. In fact, they are an essential component in various construction materials, such as a wide range of building blocks, lightweight aggregate concrete, structural concrete, as well as ballast for railroads or road coating in conjunction with bituminous materials. They can also be used as filter media for bacterial (Ausland et al., 2002) or metallic ion removal. The combination of the porous character and inertness of LWA materials makes them highly suitable for agriculture applications such as hydroponics (Dahab, 1980).

In this study, different samples of twelve Tunisian smectite-rich claystone–marlstones were assayed for production of LWAs using the quick firing process. We chose samples with different mineralogical, chemical and granulometric characteristics in order to test the influence of these variables on the technical properties of pellets. We also examined the results of the addition of different proportions of sand and used automobile oil to the clays. The physical properties of the bloated

materials obtained are reported and compared with two commercial LWAs.

2. Materials

The clayey deposits are located in the Southern Atlas domain (Fig. 1). The samples were collected at different locations: Jebel Aïdoudi (AYD₁, AYD₂) and Jebel Berda (JBD₁), belonging to the Aleg formation and ranging in age from Coniacian to Low Campanian (Burllet, 1956); samples from Oued Tefal (TFL₁), Jebel Hamadi (HMD₁) and Jebel Orbata (KB) are Campanian to Maastrichtian in age and belong to the middle member of the Abiod formation; those collected at Jebel Sehib (SHB₁), Jebel Chamsi (CHM₁), Chébika (CHB₁), Oum Kcheb (OMK₁) and Jebel Stah (JST) are Maastrichtian–Palaeocene in age and belong to El Haria formation (Burllet, 1956); and finally, those collected in the Kef Eddour region (KFED₁) are Miocene in age and belong to the Beglia formation.

The quartz sand was sampled at the Barremian Sidi Aïch formation, at the deposit of Jebel Meloussi (Fig. 1).

3. Methods

Mineralogical analyses of bulk samples were carried out by X-ray diffraction (XRD), using Philips X' Pert equipment and Cu K_α radiation. Oriented aggregates were treated with ethylene glycol and heated to 500 °C for 2 h.

The quantitative mineralogical analysis was carried out using information from chemical analyses and from XRD, according to the mineralogical peculiarities of each sample. The values obtained by the classic method (area measurement

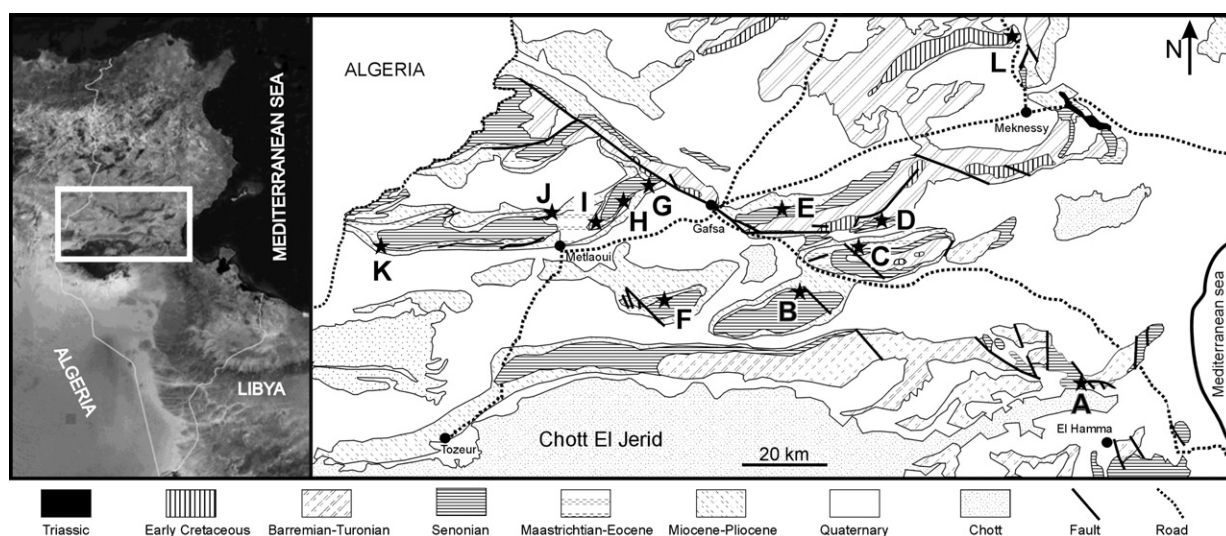


Fig. 1. Localisation of the smectitic-rich clayey deposits (A–K) and quartz sand deposit (L). A: J. Aïdoudi (AYD₁ and AYD₂); B: J. Berda (BRD₁); C: J. Chamsi (CHM₁); D: J. Hamadi (HMD₁); E: J. Orbata (KB); F: J. Sehib (SHB₁); G: Oued Tefal (TFL₁); H: Jebel Stah (JST); I: Oum Kcheb (OMK₁); J: Kef Eddour (KFED₁); K: Chébika (CHB₁); L: Jebel Meloussi (sand).

of peaks and reflective power, e.g. Schultz, 1964; Biscaye, 1965; Barahona, 1974) were corrected according to the chemical composition of the rock, following Torres-Ruiz et al. (1994).

Chemical analyses were done by ICP-ES after LiBO₂ fusion. Total organic carbon was estimated using a “Carmograph Whostoff 8” analyser. The loss-on-ignition was evaluated as percentage weight difference in one sample heated at 100 °C and 1000 °C. Grain size distribution was analysed using a Micrometrics Sedigraph 5100.

LWA materials were prepared as follows: small pellets of 10 to 12 mm in diameter were shaped by hand from fresh wet paste of powdered rock, air-dried at room temperature for several days, and then heated at 168 °C for at least 24 h. In order to prevent deterioration of the dried balls subjected to rapid “flash heat” and avoid their explosion during the final firing process, additional treatments at 600 °C (OMK₁), 700 °C (KB, BRD₁) and 800 °C (remaining samples) for at least 2 h, at a thermal gradient of 4.58 °C/min, were also effected. The dried pellets were then directly introduced into a laboratory oven pre-heated to 1180 °C and fired at this temperature for 5 min.

The properties (apparent density, fracture force, water absorption and expansion percentage) were determined (at least three measurements) on the synthesized LWAs and compared to two commercial LWAs: Argidécór® from France (used for draining soil and for decoration), and LECA® from Portugal (used in association with cement for filling).

The apparent density (AD, expressed in g/cm³) was calculated as W/V ratio, where W is the weight of the expanded aggregates and V is their volume measured by the method of sand dislocation.

The fracture force of a single aggregate (expressed in KN/mm²) was measured by pressing the aggregate until it cracked in an Autograph AG-25TA press.

Water absorption (WA) was estimated after 72 h of immersion in distilled water, and expressed in percentage weight: $WA = 100 \times (W_s - W) / W$, where W_s is the water-saturated weight, and W the original weight.

Expansion was expressed as diameter changes after firing, following the equation $EP = 100 \times (d_2 - d_1) / d_1$, where d_1 and d_2 are the diameters of the balls before and after firing, respectively.

The texture and morphology of the pellet fragments was determined by scanning electron microscopy (SEM) in a Philips XL30 microscope.

4. Results and discussion

4.1. Raw material characterization

The mineral composition of the raw materials is summarized in Table 1. Although the mineral phases are the same in all cases, their proportions vary considerably from one outcrop to another. Smectite, the most abundant clay mineral, ranges from 42 to 81%, and kaolinite content varies to a similar extent (<36%). Illite contents are normally very low and mixed layers are absent except in one sample from Oum Kcheb. Carbonates exist in almost all samples, sometimes in considerable quantities (for instance, 33% calcite and 4% dolomite in Jebel Sehib, or 19% calcite and 2% dolomite in Oued Tfal and Jebel Hamadi) although normally their values are low. Quartz and feldspars are also present, although their total contents do not exceed 9%, with the exception of the samples from J. Orbata (14% quartz and 2% feldspars) and Kef Eddour (9% quartz and 7% feldspars).

Chemical analysis (Table 2) showed that the main constituents of the raw materials are silica, alumina, and iron oxides. High CaO content (10.55 to 20.18%) was also detected in some samples, obviously related to the abundance of carbonate minerals. Na₂O and K₂O contents are mainly attributed to the clay minerals and

Table 1
Mineralogical composition of the studied samples

Location	Samples	Sm	Ill	I/S	Kao	Qz	K-Fd	Plag	Cal	Dol
Jebel Aïdoudi	AYD ₁	74	4	–	9	5	1	1	6	–
	AYD ₂	81	3	–	9	6	–	1	–	–
J. Berda	BRD ₁	63	7	–	9	7	–	2	10	2
Oued Tfal	TFL ₁	70	4	–	–	5	–	–	19	2
J. Hamadi	HMD ₁	67	1	–	2	9	–	–	19	2
J. Orbata	KB	42	10	–	19	14	–	2	13	–
Chbika	CHB ₁	62	5	–	16	3	3	–	10	1
J. Sehib	SHB ₁	53	–	–	6	3	–	1	33	4
J. Chamsi	CHM ₁	59	3	–	14	4	2	–	17	1
Oum Kcheb	OMK ₁	52	4	9	30	3	1	–	1	–
J. Stah	JST	48	4	–	36	4	2	–	1	5
J. Kef Eddour	KFED ₁	44	5	–	35	9	5	2	–	–
Jebel Meloussi	Sand	–	–	–	–	95	4	1	–	–

Sm: smectite; Ill: illite; Kao: kaolinite; I/S: interstratified illite–smectite; Qz: quartz; Cal: calcite; K-Fd: K-Feldspar; Plag: plagioclase; Dol: dolomite.

Table 2
Chemical composition of the studied samples

Samples	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	Cr ₂ O ₃	LOI	TOC	Fluxing	Si/F ^a
AYD ₁	47.74	18.59	7.39	1.98	3.85	1.94	1.58	0.92	0.27	0.03	0.03	15.30	0.21	16.74	2.85
AYD ₂	51.35	19.15	7.72	2.19	0.57	1.72	1.41	0.94	0.27	0.02	0.02	14.30	0.30	13.61	3.77
BRD ₁	46.14	16.92	7.14	2.42	6.77	0.71	1.51	0.82	0.37	0.02	0.02	16.90	0.68	18.55	2.49
TFL ₁	41.33	11.75	4.60	3.08	12.13	2.24	1.16	0.60	0.44	0.02	0.02	22.40	0.26	23.21	1.78
HMD ₁	43.99	12.18	5.15	2.73	12.04	1.28	0.93	0.59	0.52	0.02	0.02	20.20	0.71	22.13	1.99
KB	50.92	16.29	6.46	2.27	7.62	0.96	1.29	0.85	0.40	0.02	–	13.00	0.43	18.60	2.74
CHB ₁	44.68	16.90	6.73	3.19	6.47	0.98	1.77	0.86	0.45	0.02	0.02	17.60	0.40	19.14	2.33
SHB ₁	32.10	11.70	4.31	2.97	20.18	0.30	0.73	0.53	0.70	0.02	0.04	26.50	0.54	28.49	1.13
CHM ₁	41.65	16.08	5.80	1.78	10.55	1.82	1.46	0.82	0.18	0.01	0.02	19.50	0.21	21.41	1.94
OMK ₁	49.10	21.01	7.08	1.99	0.44	2.29	1.89	0.89	0.31	0.01	0.02	14.60	0.21	13.69	3.59
JST	46.25	20.76	6.90	2.93	2.67	1.16	1.30	0.91	0.28	0.02	0.03	16.70	0.40	14.96	3.09
KFED ₁	53.29	20.72	5.69	2.45	0.21	1.24	1.83	1.04	0.13	0.02	0.02	13.10	0.52	11.42	4.67
Sand	97.84	1.13	0.16	0.10	0.11	< 0.01	0.74	0.21	n.d.	< 0.01	n.d.	0.11	–	1.11	88.14

TOC: total organic carbon.

^aSiO₂/fluxing (Fe₂O₃, CaO, MgO, Na₂O and K₂O).

feldspars. The organic components in these clayey samples are in trace amounts, with the TOC ranging between 0.21% and 0.71%.

The chemical data were plotted on the SiO₂–Al₂O₃–fluxing elements (CaO+MgO+Fe₂O₃+Na₂O+K₂O) diagram (Riley, 1951). Two groups of claystone–marlstones can be observed, inside and outside the swollen area (Fig. 2). The clayey materials inside the swollen area were considered to have become suitably viscous at swelling temperature. The second group, outside the swollen area and with higher fluxing element contents (>20%) and lower Si/fluxing ratio (<2, see Table 2), was thought to have low viscosity, meaning it cannot trap a significant amount of gas and is thus prevented from swelling during firing (Riley, 1951; De’Gennaro et al., 2004). According to the mineralogical and chemical data, the gases developed during

swelling could originate from the fluxes (calcite, dolomite and/or iron derivatives) and structural water of the clay minerals. Despite the very low content of organic matter, it could also play a role during the swelling process, since it can reduce the Fe₂O₃ found in the clay and produce CO and CO₂ (Declercq and Viaene, 1993).

Finally, grain size analysis indicated that the raw materials were extremely fine, with an important clay fraction (<2 μm) ranging from 77% to 92%. The Jebel Sehib sample had exceptionally coarse grain size and a lower clay fraction (56%) (Fig. 3).

4.2. Firing procedure and expansion

Among the samples with good chemical characteristics (inside the swollen area of Riley’s diagram), expanded aggregates were only obtained from AYD₁, AYD₂, KB and OMK₁. The expansion of samples is attributed to the presence of substances (mainly calcite and clay minerals) that release gas above the pre-treatment temperatures (600, 700 and 800 °C), and/or to the formation of intermediate phases which would retain gas and release it around the swelling temperature. In the mentioned samples, the phases recognized after firing were quartz, plagioclases, mullite and hematite.

The causes of explosion during firing are not well established. Riley (1951) and Cougny (1990) gave special importance to the presence of high amounts of carbonates, whereas Blank (1976) thought some components which are completely dehydrated at high temperatures to be responsible for bloating. Sample SHB₁ is very rich in carbonates and a relatively coarse material compared to the other samples (see Fig. 3), but it produces unbloated pellets and no balls made with it

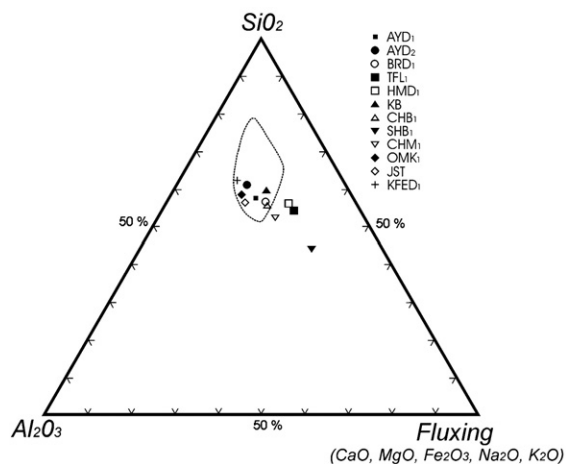


Fig. 2. Ternary diagram showing the area of the bloating material according to Riley (1951).

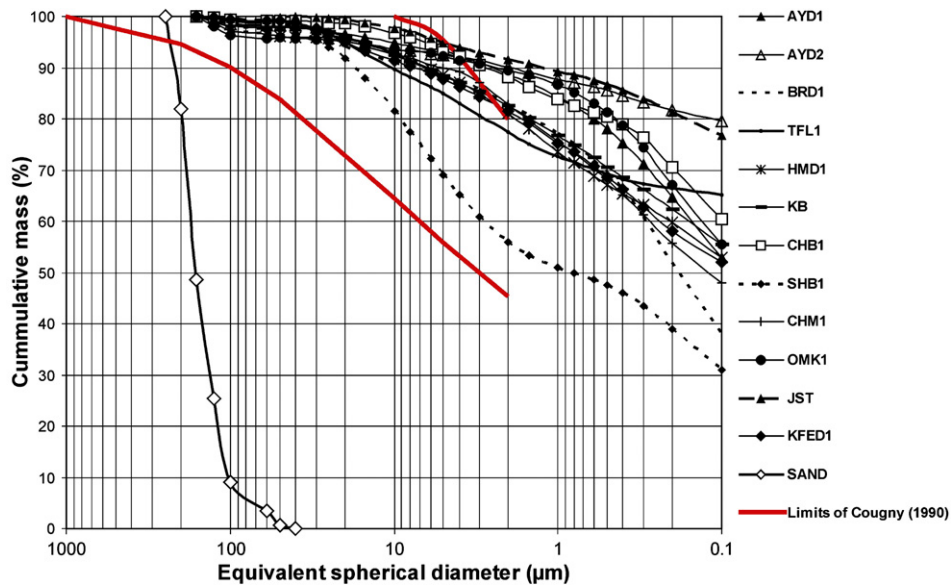


Fig. 3. Grain size distribution curves of the studied clays and quartz sand.

exploded, unlike others with less carbonates, which are very fine grained and explode. This fact suggests a possible relation between explosion and fine grain size of the original materials and contradicts the hypothesis of the abundance of carbonates to be responsible for explosion. The agglomeration of small particles in the initial wet pellets does not easily allow complete drying, thus preventing the smooth release of gases at high temperatures.

To modify the particle size distribution and check our hypothesis, we added quartz sand ranging in size from 40 to 250 μm to the initial raw materials, given that most of the samples were outside Cougny's limits (Fig. 3). Almost all the tested samples with 5% added sand required less thermal pre-treatment to avoid explosion. With the addition of 15% quartz sand this pre-treatment is not necessary. So the pellets, previously dried at 168 $^{\circ}\text{C}$, can be directly introduced into the heated kiln at 1180 $^{\circ}\text{C}$. Hence, the addition of quartz sand of an appropriate size corrected the overall particle size distribution of raw materials, resulting in complete drying at relatively low temperature and, consequently, the formation of more gas. Addition of 25% quartz sand was also tested, but expansion decreased.

In order to check the effect of mineral oil addition on expansion, as some companies producing LWAs do, we also tested the addition of 1% of used automobile oil to the mixtures of clay and quartz sand. This oil played two main roles in the expansion process: it provided gas and lowered the melt formation temperature (bloating temperature).

4.3. Expanded products characterization

4.3.1. LWA macroscopic characteristics

As a general rule, the successfully synthesized LWAs showed uniform expansion and spherical shape, with a brownish mantle and core. It should be pointed out that remarkable expansion was obtained for LWAs synthesized from AYD₁ and KB clays, and that when 15% quartz sand was added, the original regular spherical shape was not altered (except in sample KB), although a colour change to grey was observed in the core in OMK₁, and to blackish grey in the AYD samples. In comparison, the LECA[®] LWAs were asymmetric and irregular in shape with a grey mantle and core. The Argidécór[®] LWAs were spherical, with reddish mantle and black core.

4.3.2. SEM determinations on the LWA structure

SEM observations were used to compare pore distribution, pore size and shape in the mantle and core of the LWAs produced with more promising technical characteristics. Two groups can be distinguished: A) samples AYD and KB had uniformly distributed internal pores, but varied widely in both shape and size, from 4 μm to 1.4 mm (Fig. 4a), whereas the mantle had low porosity and small pores (from 4 μm to 350 μm , Fig. 4b); and B) sample OMK₁, which presented more homogeneous internal porosity, with small sizes and irregular pore shapes (Fig. 5a), and large pores in the mantle (Fig. 5b).

Addition of 15% quartz sand caused some changes. In the case of sample AYD₁, the pores in the core were

smaller but more uniformly distributed (Fig. 4c), and the mantle was unaltered (Fig. 4d), but relevant differences were found in OMK₁ clay, which showed well developed internal porosity and numerous interconnected pores in the core (Fig. 5c), while the mantle showed more abundant small pores (Fig. 5d).

Addition of used automobile oil to these mixtures gave variable results. It deteriorated some samples (AYD₁ and KB), but lowered firing temperature in other cases (AYD₂) with well developed internal (Fig. 4e) and external (Fig. 4f) pores. Pore size increased significantly with no change in firing temperature (OMK₁, Fig. 5e and f), and samples

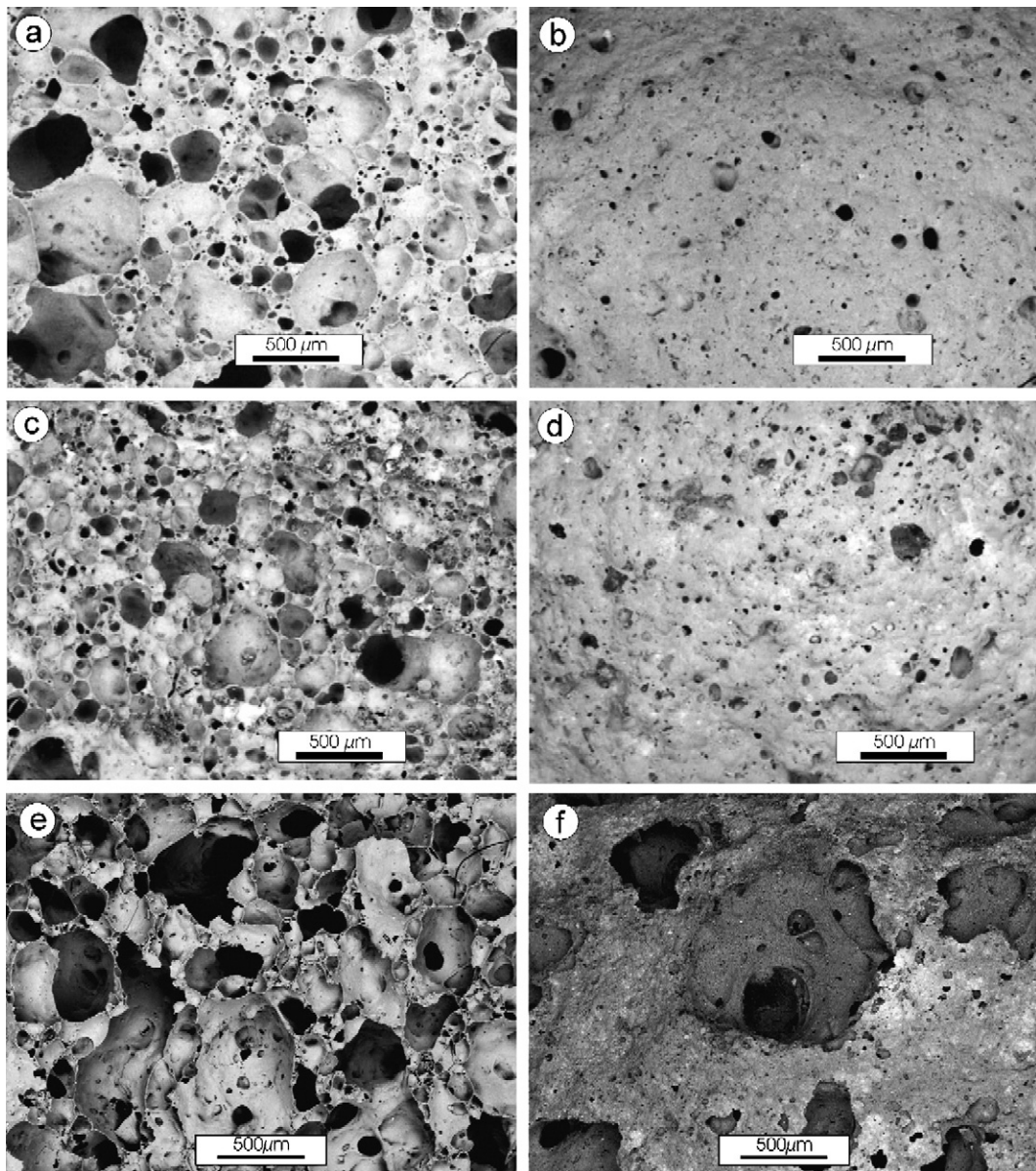


Fig. 4. Secondary electron micrographs of LWAs produced from AYD₁. a) core structure, and b) mantle structure of the LWA thermally pre-treated at 800 °C and then fired at 1180 °C for 5 min. The core shows uniformly distributed pores, but varying widely in both shape and size, and the mantle shows low porosity and small pores. Similar core (c) and mantle (d) regions are shown after the addition of 15% of quartz sand, but without thermal pre-treatment. In this case, pores in the core were smaller but more uniformly distributed and more homogeneous in size and shape, and the mantle structure kept more or less the same porosity system. LWAs produced from AYD₂ after addition of 15% of quartz sand and 1% used automobile oil, and fired at 1120 °C for 5 min, show well developed internal (e) and external (f) pores.

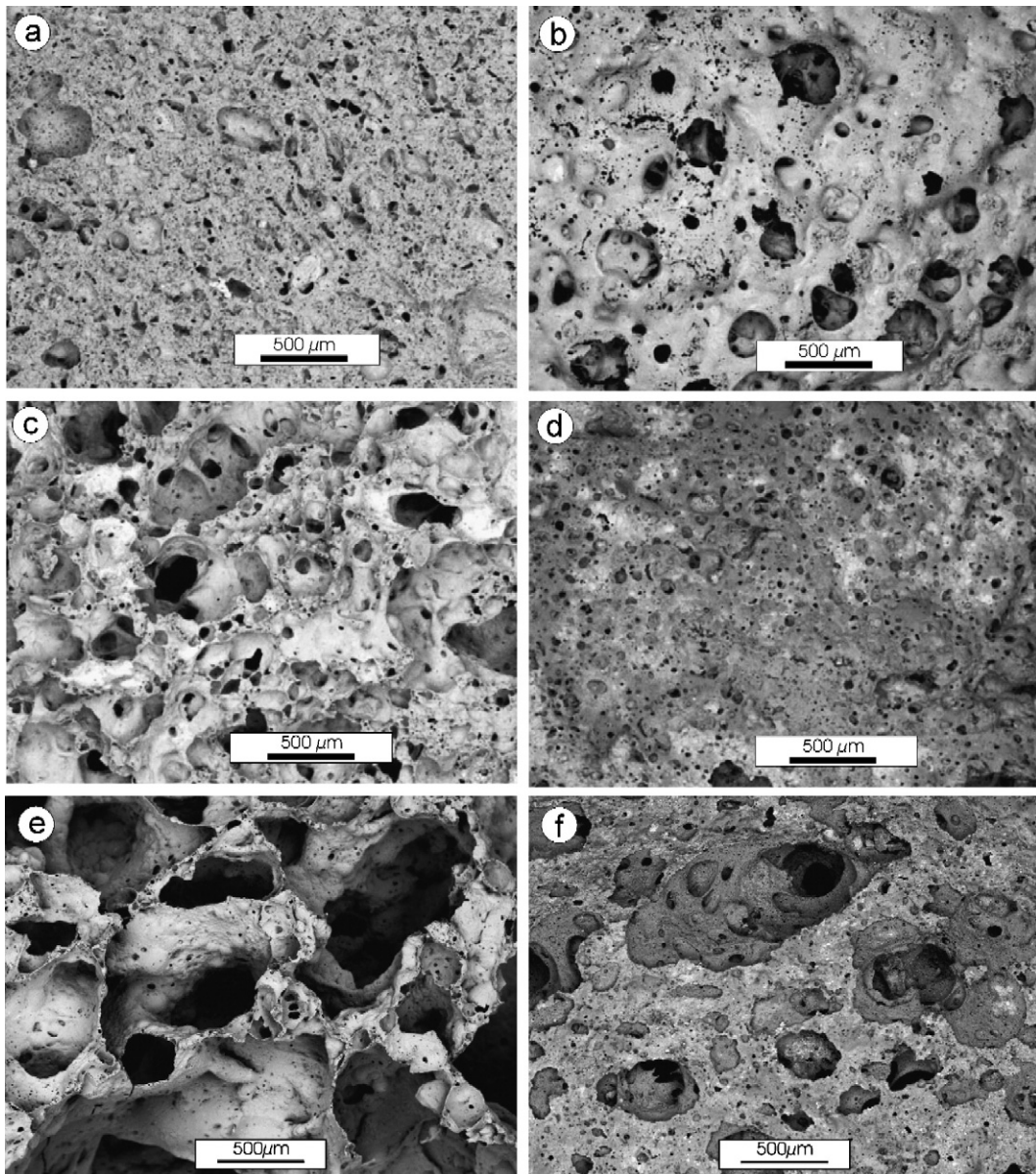


Fig. 5. Secondary electron micrographs of LWAs produced from OMK_1 . a) core structure, and b) mantle structure of the LWA thermally pre-treated at 600 °C and then fired at 1180 °C for 5 min. Core structure shows homogeneous internal porosity, with small sizes and irregular pore shapes, and mantle structure shows large pore surfaces. Similar core (c) and mantle (d) regions are shown after the addition of 15% of quartz sand, but without thermal pre-treatment. Note how core structure is now characterized by well developed internal porosity and numerous interconnected pores, and mantle structure shows more abundant small pores. Core (e) and mantle (f) structure of LWA is now shown after the addition of 15% of quartz sand and 1% of used automobile oil, and then fired at 1180 °C for 5 min. The development of large pores is evident.

particularly rich in kaolinite (JST and $KFED_1$) now expanded, whereas previously they had not done so.

4.3.3. Apparent density

The values obtained for LWAs prepared from original raw materials ranged from 0.64 to 0.89 g/cm³. However,

when sand was added, the apparent density decreased in samples AYD_1 and OMK_1 (close to that of Argidécór® LWAs, 0.56 g/cm³), and increased in samples AYD_2 and KB clays, which were the richest in SiO_2 . When oil was added density was considerably lower in all cases (0.28–0.42 g/cm³) (Table 3).

Table 3

Apparent density (AD), fracture force (FF), water absorption (WA) and expansion percentage (E) of synthesized and commercial LWAs

Samples	Firing temperature and time	AD (g/cm ³)	FF (KN/mm ²)	WA (%)	E (%)
AYD ₁	1180 °C – 5 min	0.64	0.10	6	42
AYD ₁ +5% sand	1180 °C – 5 min	0.57	0.13	8	41
AYD ₁ +15% sand	1180 °C – 5 min	0.58	0.15	9	44
AYD ₁ +15% sand+1% oil	1060 °C – 5 min		deteriorated		
AYD ₂	1180 °C – 5 min	0.73	0.23	4	32
AYD ₂ +5% sand	1180 °C – 5 min	0.83	0.18	8	25
AYD ₂ +15% sand	1180 °C – 5 min	0.79	0.21	10	28
AYD ₂ +15% sand+1% oil	1120 °C – 5 min	0.28	0.08	47	72
KB	1180 °C – 5 min	0.64	0.12	4	36
KB+5% sand	1180 °C – 5 min	0.71	0.17	3	32
KB+15% sand	1180 °C – 5 min		deteriorated		
KB+15% sand+1% oil	1180 °C – 5 min		deteriorated		
OMK ₁	1180 °C – 5 min	0.89	0.45	9	23
OMK ₁ +5% sand	1180 °C – 5 min	0.79	0.25	10	23
OMK ₁ +15% sand	1180 °C – 5 min	0.50	0.18	25	47
OMK ₁ +15% sand+1% oil	1180 °C – 5 min	0.37	0.07	48	62
JST+15% sand+1% oil	1100 °C – 5 min	0.36	0.09	49	58
KFED ₁ +15% sand+1% oil	1180 °C – 5 min	0.42	0.09	23	62
Argidécór		0.56	0.37	31	–
LECA		0.38	0.16	27	–

This decrease of apparent density in samples when 15% of sand is added suggests that more gases were generated and trapped by the viscous melt, whereas the increase of apparent density in the two last samples after sand addition (irrespective of whether content was 5 or 15%) was probably due to the increase of free silica. Consequently, viscosity prevented vesiculation of the material, since gas release occurred below the softening temperature (De'Gennaro et al., 2004). In this case, a higher firing temperature could be necessary for swelling.

The apparent density of the LWAs produced is clearly related to the expansion percentage (correlation for an exponential function: $R^2=0.962$) as shown in Fig. 6. In fact, as expansion percentage increases the pore size of the LWAs increases, resulting in a decrease of apparent density.

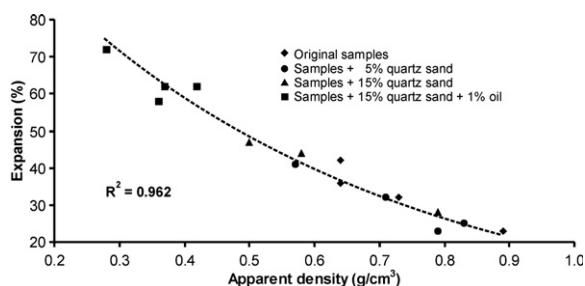


Fig. 6. Relationship between expansion and apparent density of the LWAs presented in Table 3.

4.3.4. Fracture force

The fracture force of the selected LWAs ranged from 0.07 to 0.45 kN/mm² (Table 3). The highest value of 0.45 was obtained from OMK₁, and could be related to the low porosity of the aggregates. The effect of quartz sand addition on fracture force is not clear and depends on the initial raw material. The values obtained with samples containing 15% of added quartz sand range from 0.15 to 0.21 kN/mm², intermediate between those of Argidécór® (0.37 kN/mm²) and LECA® (0.16 kN/mm²). When oil is added, fracture force is less than 0.1 kN/mm² (Table 3). The correlation between fracture force and expansion of the aggregates have a low statistical significance ($R^2=0.6023$, Fig. 7), suggesting that additional factors could affect the strength of the aggregates, especially the glassy phase and the nature of the newly formed phases (Decler and Viaene, 1993).

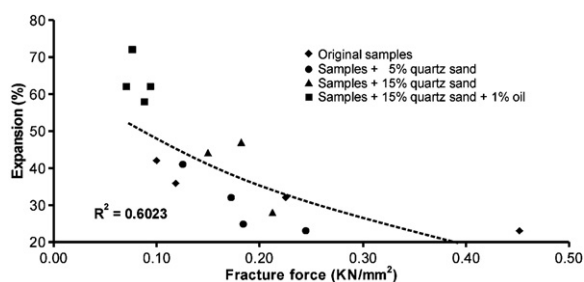


Fig. 7. Relation between expansion and fracture force of the LWAs presented in Table 3.

4.3.5. Water absorption

The applicability of LWAs for particular uses is strongly affected by water absorption. In the case of LWAs for concrete production, high water absorption is not desirable, while the opposite is true if they are to be used for supporting plant life. In our samples, the water absorption of the LWA prepared from raw materials ranged from 4 to 10% (Table 3). These values are lower than those characterizing commercial LWAs, namely Argidéc® (31%) and LECA® (27%). When quartz sand was added, water absorption capacity increased, reaching a maximum of 25% in sample OMK₁ (Table 3). This value rose to approximately 50% with the addition of oil. In fact, absorption increases with increasing permeable porosity, formed by interconnected pores in the core of the aggregates.

5. Conclusions

We have evaluated some Tunisian smectite-rich claystone–marlstone rocks for use in lightweight aggregate production. The very small grain size of the initial raw materials results in explosion of the final LWAs during the firing process. To avoid such phenomena, thermal pre-treatment of the dried balls at intermediate temperatures is necessary. The addition of quartz sand, with <250 μm grain size, is then proposed to eliminate both the thermal pre-treatment and the explosion of the LWAs. The appropriate quartz sand addition was estimated to be about 15%.

The properties of the LWAs obtained with the addition of sand are comparable to those of commercial products (Argidéc® and LECA®). These preliminary results indicate that some of the investigated Tunisian smectite-rich clays are potential candidates for the production of LWAs with acceptable physical properties.

The synthesized LWAs can be classified into:

- LWAs appropriate for civil engineering work, especially those obtained with the addition of 15% quartz sand to the Jebel Aïdoudi clay (AYD1), and those obtained with the addition of 15% quartz sand and 1% used automobile oil to Kef Eddour clay (KFED₁).
- LWAs appropriate for agricultural applications due to their high water absorption capacity. These consist of the aggregates obtained by the addition of 15% quartz sand to Oum Kcheb clay (OMK1) and 15% quartz sand and 1% used automobile oil to Jebel Stah (JST), Oum Kcheb (OMK1) and Jebel Aïdoudi (AYD2) clays.

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