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**Belmonte, Louise Josefine; Bertelsen, Ida Maria Gieysztor**

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## **EVALUATION OF THE POTENTIAL FOR USING GREENLANDIC MARINE SEDIMENTS FOR BRICK PRODUCTION**

**Louise Josefine Belmonte <sup>(1)</sup>, Ida Maria Gieysztor Bertelsen <sup>(1)</sup>**

(1) Dept. of Civil Engineering, Technical University of Denmark, Lyngby, Denmark

### **Abstract**

Fine grained marine sediments from near the Greenlandic towns of Ilulissat, Kangerlussuaq and Sisimiut were assessed as raw materials for local production of building bricks. The assessment included both analysis of the sediment characteristics and physical properties of miniature test brick pellets. The sediment samples were, in general, very similar in respect to the investigated properties and compared well with brick clays from other parts of the world. The variable chloride content observed in two of the sediments could be a concern and should be investigated further.

### **1. Introduction**

The population is increasing in Greenlandic towns and the present housing situation is critical, due to long waiting lists and poor conditions of the current buildings. In 2012 the government of Greenland reported that 4500 state-owned flats and terraced houses, which constitute approximately 20 % of the housing in Greenland, were dilapidated [1]. In order to accommodate an increasing population and satisfy the demands for housing, it is therefore vital for the government of Greenland to construct new homes for the future.

The construction process will require new building materials, however, as most of the construction materials used in the country today are imported (mainly from Denmark and Europe), it is furthermore of great importance to investigate the potential for local building material production. In West Greenland, vast occurrences of fine-grained marine glaciogene sediments, which have been uplifted above sea level and to some extent depleted of their saline pore water, are commonly encountered. These occurrences have not yet been exploited, but are often found in close vicinity to towns, which make them easily accessible for industrial purposes. Recent research from other areas of the world has established the potential of producing masonry bricks from marine sediments (e.g. [2] and [3]). Although bricks are not commonly used in Greenland today, they have several potential advantages, such as high durability, low maintenance requirements and high fire resistance, which would make them an attractive building material in the arctic to subarctic climate.

In this paper, marine sediments were collected from three different localities near the towns of Ilulissat, Sisimiut and Kangerlussuaq on the Greenlandic West coast and screened in order to determine their suitability as raw materials for brick production. The screening involved both sediment characteristics and characterisation of basic properties of small fired miniature brick pellets.

## 2. Experimental procedure

The sediment characterisation included determination of grain size distributions, plasticity (Atterberg limits), carbon, sulphur and chloride content, and major element chemistry. The grain size distributions were analysed according to [4] (Part 4) by wet sieving ( $> 63 \mu\text{m}$  fraction) and the hydrometer method ( $< 63 \mu\text{m}$  fraction). The natural water content and plastic properties were measured according to [4] (Part 1 and 12). The contents of total carbon and sulphur were measured on a 0.5 g dry sample using the combustion infrared detection method on a LECO CS-200 high frequency oven. For determination of the chloride concentration, a measured amount of dry sample was dispersed in a known quantity of distilled water, filtered through a  $0.45 \mu\text{m}$  filter and analysed by ion chromatography (IC). Major-element analyses were determined using the X-ray fluorescence (XRF) technique.

For the production of the brick pellets (diameter: 20 mm, height: 3-4 mm and weight: 2 g), the sediments were dried at  $105 \text{ }^\circ\text{C}$  for at least 24 hours and then lightly disaggregated using a mortar and pestle. Larger visible rock fragments were removed. The dry sediments were mixed with distilled water in order to obtain a moisture content of 10 %. Dry-pressed pellets were produced by uniaxial compression in an Instron 6025 press. A maximum pressure of 47 MPa (equivalent to 14.8 kN) and a compression rate of 0.25 mm/min were applied to the pellets.

The pellets were dried at  $105 \text{ }^\circ\text{C}$  for at least 24 hours, before being fired at  $1000^\circ\text{C}$  for 1 hour in a Vecstar laboratory Furnace. An average heating rate of  $6.8^\circ/\text{min} \pm 2.5^\circ/\text{min}$  and cooling rate of  $1.9^\circ/\text{min} \pm 0.5^\circ/\text{min}$  was applied for the firing. The diameters of the pellets were measured after production and firing in order to determine the total shrinkage. Water absorption, open porosity and bulk density were measured according to [5].

## 3. Results and discussion

### 3.1 Raw material characterisation

In Figure 1, the grain size distributions of the Greenlandic marine sediments from this study and previous studies are plotted and compared to distributions of sediments used for brick production elsewhere in the world. The Greenlandic sediments generally contain more of the 2-60  $\mu\text{m}$  fraction (silt) in comparison to the brick clays from Denmark, Italy and Brazil. However, the grain size distributions of the Portuguese brick clays demonstrate that even sediments with high silt contents can be used for brick production.

In Table 1, the major element distribution of the Greenlandic marine sediments from Ilulissat and Kangerlussuaq are compared to brick clays from other areas of the world. The chemical compositions of both the Greenlandic sediments and the brick clays are dominated by  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$ , which constitute 80-82 wt % for the Greenlandic sediments and 75-93 wt % for the brick clays. The fluxing oxides (i.e.  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{MgO}$  and  $\text{CaO}$ ), which can reduce the melting temperature and enhance the sintering process, constitute 12-16 wt % for the Greenlandic sediments and 1-9 wt % for the brick clays. This difference is caused by the higher  $\text{Na}_2\text{O}$  and  $\text{MgO}$  content in

the Greenlandic sediments, and indicates that the Greenlandic sediments have a larger fluxing potential compared to the brick clays.

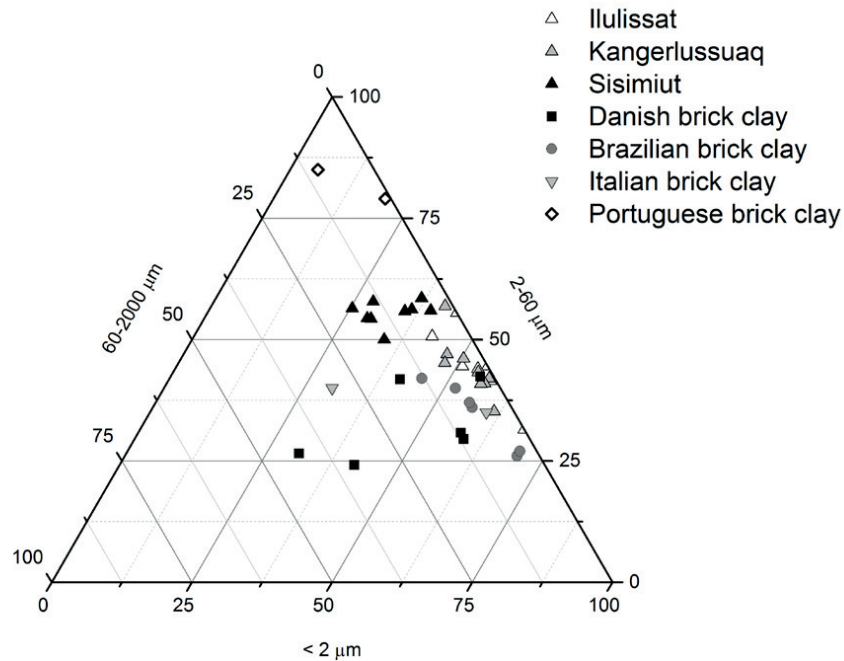


Figure 1. Grain size distribution. Greenlandic samples (Ilulissat, Kangerlussuaq and Sisimiut): results from this study and [11], [6], [12], Brick clays: [9], [7], [13], [10].

Table 1. Major element distribution of marine sediment from Ilulissat and Kangerlussuaq compared with distributions of brick clays (producing red bricks) from Brazil, Denmark, Portugal and USA. No data from Sisimiut is available.

Locality Reference	Marine sediments		Brick clay (red)			
	Ilulissat	Kangerlussuaq	Brazil	Denmark	Portugal	USA
		[6]	[7]	[8], [9]	[10]	[3]
SiO <sub>2</sub> (wt %)	61.1	58	39.3-41.4	55.5-77.0	49.4-57.4	60.5
TiO <sub>2</sub> (wt %)	0.6	0.8	0.8-0.9	0.7-1.0	No data	1.0
Al <sub>2</sub> O <sub>3</sub> (wt %)	14.5	16.2	27.8-31.2	9.6-20.1	22.7-30.8	20.1
Fe <sub>2</sub> O <sub>3</sub> T (wt %)	6.5	6.6	5.1-9.9	3.8-7.8	5.8-7.6	8.1
MnO (wt %)	0.1	0.1	No data	0.0-0.1	No data	0.1
MgO (wt %)	3.5	3.8	0.2-0.4	0.9-1.9	0.6-1.0	1.0
CaO (wt %)	2.4	4.4	0.1-0.2	0.0-3.0	0.1-0.2	0.1
Na <sub>2</sub> O (wt %)	3.3	4.5	0.2-0.6	0.5-1.6	0.7-1.0	0.4
K <sub>2</sub> O (wt %)	2.8	2.9	0.8-1.2	2.2-3.5	0.9-1.5	2.6
P <sub>2</sub> O <sub>5</sub> (wt %)	0.1	0.2	No data	0.1-0.2	No data	0.1
LOI (wt %)	5.1	2.4	15.1-18.7	3.9-10.1	8.6-10.9	6.1

In Figure 2, the plasticity indices are plotted against the plastic limits in order to evaluate the moulding properties of the sediments. As seen from the figure, the sediments from Ilulissat and Kangerlussuaq generally plot within the boxes for optimal and acceptable extrusion properties, which indicate that they are suitable for processing by the stiff-mud (extrusion) method according to [15]. The samples from Sisimiut have low plasticity indices and plot outside the boxes, indicating that these sediments are more suited for the dry press process [15].

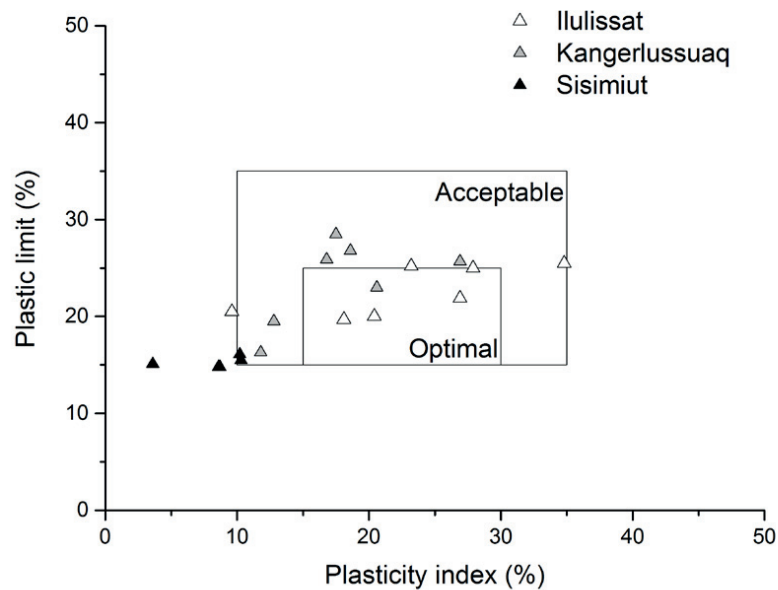


Figure 2. The plasticity index plotted against the plastic limit. The two boxes define conditions for optimal and acceptable extrusion behaviour according to [14].

Table 2. Total carbon (TC), sulphur (S) and chloride (Cl<sup>-</sup>). The chloride values contain data from [16], [12]. Values in parentheses are standard deviations.

	Ilulissat	Kangerlussuaq	Sisimiut
TC [wt%]	1.42 (0.16)	0.02 (0.00)	0.17 (0.00)
S [wt%]	0.09 (0.03)	0.03 (0.00)	0.06 (0.08)
Cl <sup>-</sup> [mg/kg]	0-31	604-9863	2.6-3012

The results of the total carbon (TC), sulphur (S) and chloride (Cl<sup>-</sup>) analysis are shown in Table 2. The TC and S values are within the ranges of 0.02-1.42 wt% and 0.03-0.09 wt%, respectively, and are below the maximum levels of 1.5 wt% and 0.1 wt%, respectively, specified for other brick clays [17], [8]. The higher TC values observed for the Ilulissat samples, could possibly be explained by the presence of small marine shell fragments (although not observed), or a higher content of organic carbon compared to the other samples.

Soluble chloride in brick clays can cause corrosion of kilns and lead to acid emissions during firing [18]. Furthermore, it can also give rise to unwanted surface efflorescence, or even mechanical weathering of the fired bricks [15]. Brick clays with a chloride content > 1000 mg/kg are usually not considered suitable for bricks [8]. The chloride contents are highly variable for the samples

from Kangerlussuaq and Sisimiut and demonstrate large local variations in the two areas. However, in spite of chloride values exceeding 1000 mg/kg, no surface efflorescence was detected on any of the fired pellets after submersion in water. The chloride contents in the Ilulissat samples were all below 1000 mg/kg and therefore not considered problematic.

Table 3. The total shrinkage (TS), open porosity (OP), bulk density (BD) and vacuum water absorption (VWA) of the fired pellets. Values in parentheses are standard deviations.

	Ilulissat	Kangerlussuaq	Sisimiut
TS (%)	0.6 (0.0)	0.1 (0.2)	0.1 (0.2)
OP (vol %)	28 (0.9)	31 (0.6)	22 (1.3)
BD (kg/m <sup>3</sup> )	1970 (23)	1870 (15)	2130 (30)
VWA (%)	14 (0.6)	16 (0.5)	10 (0.7)

### 3.2 Brick pellet characterisation

The characteristics of the brick pellets are presented in Table 3. Bulk densities of clay bricks used in the building industry, have been reported to be in the range of 1510-2380 kg/m<sup>3</sup> [19], [13], [20] and open porosities in the range of 18.8-39 vol% [20]. The bulk densities and open porosities found for the pellets in this study are therefore acceptable. The total shrinkage of clay bricks is usually less than 8% [15] and the values for the brick pellets produced in this study are far below this limit. According to [21], building bricks are classified with respect to weather grades based on their resistance to damage by freezing. In Greenland, facing bricks (i.e. bricks which are exposed to weathering) should conform to the highest grade (severe weathering grade), where the water absorption after 24 hours submission in cold water must not exceed 8%. The fired pellets all have higher water absorption, which is why improvements in the production procedure are required. According to [3], an increase in firing temperature lowers the water absorption, although it could also enhance melting and shrinkage due to the high fluxing potential of the Greenlandic samples.

## 4. Conclusions

The initial investigations of marine sediments from Ilulissat, Kangerlussuaq and Sisimiut demonstrated a promising potential as raw materials in brick production. The variable chloride contents in samples from Sisimiut and Kangerlussuaq could be a concern and should be investigated further.

The plastic properties indicated that the sediments could be processed by extrusion or dry pressing in order to produce bricks. Improvements, such as an increase in the firing temperature, are required in order to obtain sufficiently low water absorption properties.

## 5. Acknowledgements

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