Construction and Building Materials 48 (2013) 160–165

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Use of clay bricks incorporating treated river sediments in a demonstrative building: Case study

Fayçal El Fgaier [a,b], Zoubeir Lafhaj [a,*], Christophe Chapiseau [b]

[a] Ecole Centrale de Lille, Villeneuve d'Ascq, 59651 Cedex, France
[b] Briqueteries du Nord, 9ème Rue, Port Fluvial, Lille, 59003 Cedex, France

HIGHLIGHTS

- Construction and building materials.
- Bricks with treated sediments.
- On site study.
- Experimental work.
- On site thermal and air quality test.

ARTICLE INFO

Article history:
Received 19 May 2012
Received in revised form 22 May 2013
Accepted 17 June 2013
Available online 26 July 2013

Keywords:
Brick
River sediments
Air quality
VOCs
Formaldehyde

ABSTRACT

The objective of this study is to demonstrate the feasibility and the practical use of the sediment-amended bricks in a demonstrative building. The air quality inside the building and the thermal quality were studied. The experimental study of the air quality is focused on the presence of VOCs, formaldehyde, ultrafine particles, including PM10 and 2.5, and the measurement of climatic parameters.

The results obtained indicated that VOCs and metals concentrations in brick dust do not exceed the regulatory limit values, and this is not the case for the concentration of formaldehyde and the concentrations of PM10 fraction, which can be explained by the adjaction of this demonstrative building to an industrial site. On the other hand, the thermal test, in situ, demonstrates that the introduction of treated sediments does not have a significant impact on the thermal performance of construction.

1. Introduction

Over the next 15 years, a volume of three million m^3 of river sediments is to be dredged in the north of France in order to maintain a normal river activity in this region. An important part of these sediments is currently polluted. This pollution is linked to the industrial history of the region where certain activities, like iron and steel industries, metallurgy of nonferrous ores and energy sectors remain polluting. Contamination is mainly due to organic (PAHs, PCBs, TBT and dioxins) and inorganic (heavy metals: lead, chromium, zinc, copper) pollutants, which can end up in drains, rivers, and coastal waters, thus contaminating water resources, soils and polluting the environment.

Dredged material has to be managed and since international and European laws have become more stringent, its management has become an environmental and economical concern for a large number of countries.

Various alternatives to the disposal of the processed material have been investigated like sea deposit, landfilling and treatment processes. The effect of disposal in open-water has been largely studied [1,2]. Landfilling requires large spaces and long-term monitoring; however, it is less accepted by the public opinion (NIMBY). On the other hand treatment processes permit a reduction in toxicity and volume of dredged material, but in comparison with open-water and upland disposal, the treatment cost is not yet competitive enough [3]. This underlines the necessity to find ecological valorization paths for processed material to make these alternatives economically competitive. Thus, researchers have started to study alternative ways to incorporate large amounts of processed sediments into different aspects of construction and building materials, where raw sediments have to be treated before being valorized.

In recent decades several types of waste materials have been assessed as raw materials for brick making, for example lightly contaminated harbour sediments [4–6], waste bricks [7], limestone dust and wood sawdust [8], processed waste tea [9], reservoir

* Corresponding author. Tel./fax: +33 320336039.
E-mail address: zoubeir.lafhaj@ec-lille.fr (Z. Lafhaj).

0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.06.030

sediments mixed with fly ash [10], dried sludge collected from industrial wastewater treatment [11–13], incinerated sewage sludge ash [14–16], fly ash [17], granite sawing waste material [18], water treatment residual with excavation waste soil [19], steel dust [20] and kraft pulp production residues [21].

Considering their perpetual availability, particle sizing and chemical composition, sediments are regarded as a suitable raw material for brick production. Moreover, the beneficial use of polluted sediments offers a practical contribution to maximizing the conservation of traditional brick-making raw materials.

The application of treated river sediments, with different percentages, as a partial replacement material in brick making has been previously investigated [22]. The polluted sediments were stabilized using the Novosol® process which consists of two major phases: phosphatation and calcination. This process was developed and patented by the Solvay Company [23]. Indeed, during the last 7 years our laboratory has realized a large number of experiments in order to study the feasibility of using polluted river sediments, after treatment, in construction materials (mortar, road materials, clay bricks).

Consequently, a full-scale industrial experiment was conducted to demonstrate the practical incorporation of treated river sediments into brick production as a suitable alternative to their current disposal paths. Treated sediments were introduced into the brick-manufacturing process as a replacement of sand (quartz sand) with a substitution ratio of 15%. This material was introduced without any alteration of the existing process lines of Briqueteries du Nord, a brick factory in the north of France. Approximately 15,000 samples of sediment-amended perforated bricks ($220 \times 220 \times 60$ mm^3) were produced. The results obtained from several qualification tests (compressive strength, freeze and thaw resistance, water absorption) have demonstrated that sediment-amended bricks have at least the "clay bricks" specifications and environmental requirements given by the existing standards. Moreover, leaching tests undertaken on sediment-amended bricks showed that the concentrations of heavy metals in the leachates were largely inside the regulatory limits thus, sediment-amended bricks can be regarded as non-hazardous material. For more details see [24].

The present work aims at studying the feasibility of the use of these bricks, containing treated river sediments, in the construction of a small building (area of 20 m^2). The construction of the latter will be described. Finally, experimental tests were carried out to study the efficiency of the use of these bricks and of the quality of the building. Mainly the air quality inside this building was studied but also the building's thermal quality.

2. Conception of the construction

The objective of the construction of this demonstrative building is to demonstrate the practical use of sediment-amended bricks in real conditions. Treated sediments were introduced into the brick-manufacturing process as a replacement of sand with a substitution ratio of 15%. Indeed, a granular distribution was carried out on treated sediments, sand and natural clay. The results showed that particle size TS can be considered as silty sand [24].

This material was introduced without any alteration of the existing process lines of BDN. The sediment-amended mix design was composed of: 15% of treated sediments, 5% of sand and 80% of clay. However the results of this experiment were be used to guide other trials where a higher quantity of treated sediment will be valorized. This choice of 15% of TS was motivated by the preservation of the existing industrial processes in order to anticipate any problem associated with materials.

2.1. Qualification of brick

The results of qualification tests undertaken on sediment-amended bricks are presented in Table 1 compared to those of the standard one [24].

This previous study showed that the sediment-amended bricks have successfully passed the different tests required by French Standards in order to assess the suitability of a brick to be used in construction.

2.2. Demonstrative building

To complete the tests already carried out in laboratory in previous studies and to study the impact of environment on the sediment-amended bricks, a small building (20 m^2) was built mainly with these new recycled bricks, as shown in Fig. 1. The choice of the disposition and dimensions of the building are related with the orientation and conception. The building design is optimized according to the urban planning code. Indeed, the surface of the building was limited to 20 m^2 in order to simplify the procedure, so that there was no need to request a building permit.

Fig. 2 shows main pictures of the construction steps. Different tests were carried out to study the efficiency of the use of these bricks and of the quality of the building.

3. Tests and results

3.1. Identification and characterization of the air quality

The quantities and types of substances released in the environment modify the air quality. This appears mainly in two ways: as gases (VOCs, combustion gases, etc.) and as suspended particles (dusts). Breathing of contaminated air represents the most common exposure. In this part of the work, tests are conducted on the emissions of substances from the dust of sediment-amended bricks, which can be released in large quantities in the air during the construction, as well as on the air quality inside the building.

3.1.1. Evaluation of exposure to volatile chemical agents on brick dusts

The objective is to identify the types of substances and their concentrations in the dusts for sediment-amended and BdN-standard bricks. This test makes sure that no hazardous dust will be released in workplace environment, which could affect the health of the worker.

Figs. 3 and 4 show the test disking of two bricks, and the procurement of dusts. Then, these samples were analyzed by ICP-MS (inductively coupled plasma – mass spectrometry) in an acid solution, in order to determine the concentrations of different substances.

The results, presented in Tables 2 and 3, show that the sediment-amended brick has higher concentrations than the standard

Table 1
Results of qualification tests of sediment-amended and BdN-standard bricks [24].

	BdN-standard brick	Sediment-amended brick
Compressive strength (MPa)	22	36
Porosity (%)	17	15.4
Water absorption (%)	8.51	7.5
Permeability (m/s)	9.5×10^{-7}	7×10^{-8}
Firing shrinkage (%)	7	10
Weight loss (%)	0.13	0.36