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Valorization of seashell by-products in pervious concrete pavers

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HIGHLIGHTS

- Seashell By-Products (SBP) size highly influences the granular arrangement of matrix.
- The SBP can effectively replace gravel 2/6 mm for pervious concrete pavers.
- SBP 2/4 mm provides a good compromise for the overall composition of the matrix.
- SBP 4/6.3 mm decrease in mechanical strength and promoting the water infiltration.
- The compaction pressure into a single layer of 7.4 kPa is optimal with good strength.

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ABSTRACT

Seashell By-Products (SBP) are produced in an important quantity in France and are considered as waste. This paper studies their use as a partial replacement of aggregates in pervious concrete pavers considered as an environmentally friendly building material. After designing the control pervious concrete pavers by investigating the energy and the pressure compaction, the coarse aggregate fraction were partially (20% or 40% by mass) replaced by SBP obtained from the Crepidula shell. The crushed Crepidula seashell of 2/4 mm and 4/6.3 mm were used to make new seashell by-products based pavers. In this paper, the mechanical and hydrologic properties of both pervious concrete pavers were determined. Results show that the seashell by-products have the potential to be used as aggregate. The mix design allows achieving both a compressive strength of 16 and 15 MPa for respectively the control pervious concrete pavers and the seashell by-products based pavers and a permeability coefficient in the range of 3–8 mm s^{-1}.

1. Introduction

According to the French Union of Aggregate Producers [1], in France, almost 400 million tons of aggregates are consumed each year, i.e. 6 tons per inhabitant. However, most of the aggregates used are natural aggregates which are usually excavated from river beds, quarries, dredged from sand or shingle banks under the sea. In order to reduce the environmental impact of building materials and specially natural resource consumption, the reuse of waste and by-products is one of the solutions. For aggregates, many studies [2–6] have been carried out to investigate the replacement of natural aggregates in concrete by recycled aggregates, slag aggregates, and recently seashells.

Regarding the seashells, it was reported [4–6] that they are a hard material that can produce good quality concrete, however, a higher cement content may be required. Moreover, due to the angularity of the shells, additional cement paste is required to obtain the desired workability. Aggregate containing complete shells (uncrushed) should be avoided as their presence may result in voids in the concrete and lower the compressive strength.

In Europe, France has an important fishing and shellfish farming industry that produces nearly 200,000 tons of shells from shellfish breeding and nearly 50,000 tons of shellfish per year from fishing [7]. These activities generate thousands of tons of seashell by-products (empty shells) to be discharged, as they are considered as waste. For the moment, some attempts has been made in France to recycle them as soil conditioner [8] or animals food [9] but none of these attempts gave satisfaction in terms of viable and added value recycling.

In this study, Seashell By-Products (SBP) from the French west coast were prepared and used to partially replace natural aggregates to make a specific concrete: pervious concrete pavers. Pervious concrete is an environmentally friendly material and an effective means to meet growing environmental demands. Pervious concrete is used to prevent from flooding during heavy rain and to increase the water infiltration into the soil [10,11].

Pervious concrete uses the same materials as conventional concrete, with the exceptions that the fine aggregate is nearly or entirely eliminated, and the size distribution of the coarse

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Table 1
Physical and chemical properties of cement CEM I 52.5 R.

Chemical analysis (%)			Physical properties	
CaO	63.4		Specify gravity (kg m^{-3})	3140
SiO_2	19.2		Specific surface Blaine (cm^2 g^{-1})	4900
Al_2O_3	4.5		Compressive strength (MPa)	
Fe_2O_3	3.9		2 days	39
MgO	1.1		7 days	53
SO_3	3.5		28 days	64
K_2O	0.90		Initial setting time (min)	170
N_2O	0.07			
Loss on ignition	2.6			
Phase composition	C_3S	C_2S	C_3A	C_4AF
	68%	9%	6%	13%

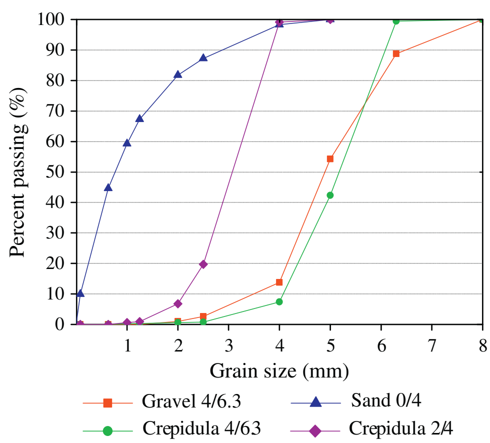

Fig. 1. Grain size distribution of natural aggregate and crushed crepidula shell.

aggregate is kept narrow, allowing for relatively little particle packing. A system of interconnected voids (15–35%) is created resulting in a highly permeable concrete that drains very quickly [10–12]. The compressive strength of the material ranges from 2 to 28 MPa [10,11]. The draining rate of pervious concrete will vary with aggregate size and density of the mixture, but will generally fall within the range of 1.35–12.2 mm/s [11]. For parking lots, a design compressive strength of about 13.8 MPa (2000 psi) is desired, and even lower strengths may be acceptable when the concrete receive light vehicular loads [13].

2. Experimental program

2.1. Materials

2.1.1. Cement and aggregate

The cement used in this study is an Ordinary Porland Cement (OPC) CEM I 52.5 R. The chemical and physical properties of this cement are summarized in Table 1. This cement contains small quantities of C_3A (see Table 1) that reduces its water demand [14] and increases the compressive strength at 7 days approximately 80–90% value at 28 days.

The alluvial quartz sand with a grain size 0/4 mm was used. This sand presents a specific gravity of 2620 kg m^{-3}, an absorption coefficient of 0.50% and a fineness modulus of 2.81.

To ensure the infiltration capacity of pervious concrete, the selection of aggregate monogranular (single-sized aggregates) is critical to achieve the interconnection of the porous system [10,11]. The size distribution of gravel and sand is given in Fig. 1.

The monogranular angular aggregate fraction 4/6.3 mm was employed with a specified gravity of 2740 kg m^{-3} and water absorption of 0.48%.

2.1.2. Seashell by-products

To evaluate the possible use of Seashell By-Products (SBP) as aggregate in pervious concrete pavers, crepidula seashell was chosen. This seashell is very abundant [15] on the on the Normandy and Brittany coasts.

Crepidula (Fig. 2a) were subjected to different preparations such as washing, grinding and screening (Fig. 2b and c) to obtain different fraction and grain size distributions. In this research, we crushed the crepidula by one crusher laboratory. Effectively, crushing shells provides granular particle >63 µm and fine fraction

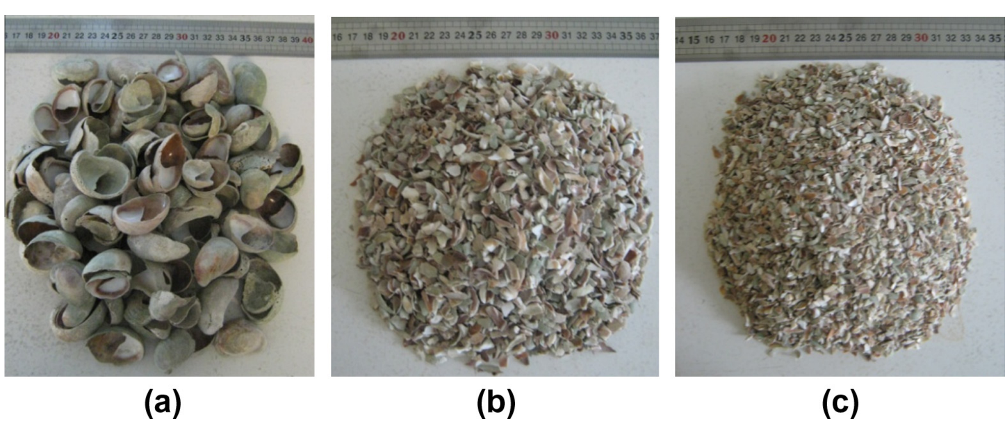

Fig. 2. Crepidula; (a) Crude crepidula; (b) Crepidula 4/6.3 mm; and (c) Crepidula 2/4 mm.

Table 2
Physical and chemical properties of the crushed crepidula and aggregates.

Characteristics	Crushed crepidula		Aggregates	
	D 2/4 mm	*D* 4/6.3 mm	Coarse aggregate 4/6.3 mm	Sand 0/4
Specific gravity (kg m^{-3})	2716	2729	2740	2620
Water absorption (%)	2.25	2.02	0.48	0,5
Chloride ion content (%)	0.065	0.065	0	0
Organic matter content (%)	1.86	1.86	0	0