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Dredged marine sand for harbour concrete pavement

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Abstract:
Dredging works are usually required to maintenance activities in many ports all over the world and represents a huge volume of disposal material. The use of dredged aggregates can be considered in several applications as erosive process control, coastal stabilization, beach replenishment, production of construction materials (aggregates, bricks, concrete), for sub layers of road engineering with stabilized materials, or for construction works (quarry fillings, disposal waste cappings).
Researches revealed the feasibility of dredged marine sand (DMS) in the construction of base and sub-base harbour pavements incorporating this material to hydraulic binder mixes (cement and/or lime with additives) in order to improve the grading of aggregates and correct the granular skeleton. Its main objective is to improve the packing and to obtain the compressive properties required for geotechnical applications.
In this work the study of dredged marine sand (DMS) from the Port of Sant Carles de la Rápita (Tarragona, Spain) as constructive material is presented. The analysis of chemical and physical characteristics of DMS is described. Two experimental phases were carried out once these characteristics were determined. DMS was used in the production of concretes as fine aggregates. A pilot experience was carried out with concrete port pavements produced in industrial scale. Fresh and hardened properties of the concretes were determined and compared to the control mix. Results show satisfactory behaviour of DMS as constructive material when incorporated in concrete as corrective sand.
Keywords:
Dredged marine sand – Mortar – Concrete – Fine sand corrector – Polypropylene fibers – Unconfined compressive strength – Flexural strength – Workability properties

1. Interest

Dredging works represents a huge volume of disposal material and are usually required to maintenance activities in many ports all over the world. This material can be used in several coastal applications but also as construction material (bricks and aggregates) or

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construction works (foundation fill, dikes, etc.). The increment of marine aggregate used as construction material for concrete and fills for reclamation projects has been observed once considerable economic and environmentally advantages indicates it as a new source of materials.

Pavement enhancement could be considered the main application for dredged marine sand (DMS) once its grading distribution leads to better compaction. Research works carried out by many authors COLIN (2003), DUBOIS *et al.* (2009), ZENTAR *et al.* (2008), KAMALI *et al.* (2007) and LEVACHER *et al.* (2006) using dredged marine sediments in the bases and sub-bases of harbour pavement constructions revealed that the studied material yields final properties compatible with the usual design requirements.

A pilot experiment at industrial scale has been developed with DMS from the Port of Sant Carles de la Rapita (Spain) as construction material. It was used in the execution of three section of a harbour concrete pavement with 30 MPa design strength as described on LIMEIRA *et al.* (2010). Concrete was produced at industrial scale in a homologated plant and used in the execution of three experimental sections of a harbour pavement (15 m long, 5 m wide and 25 cm thick, see figure 1). Three different concretes were produced: C1 (control concrete), C2 (concrete made with DMS as fine corrective sand) and C3 (concrete made with DMS as fine corrective sand and reinforced with plastic fibers PF). The fresh and hardened properties obtained were compared with those of control mix.

Referred work assesses DMS used as fine granular corrector with 18% substitution ratio of raw sand (0-2 mm) in the concrete dosage. Percentage is related to the total fine aggregate content in kg per m^3 of concrete. Further research developed by LIMEIRA *et al.* (2011) considered raw sand (0-5 mm) substitution ratio varying from 15% to 35% in order to validate the beneficial use of DMS in concrete dosage.

Figure 1. Pavement execution, after LIMEIRA (2011).

2. Materials and experimental program

2.1 Materials

Previous physical and chemical characterization of DMS is necessary in order to verify the grading, mineralogical components and the possible presence of contaminants. The concentration of chlorides and sulphates is also essential considering the marine environment and the durability of the concrete pavements. Chemical and physical characterization according to CEDEX specifications (1994) were determined on DMS indicating a negligible contaminant level in all samples studied as described on LIMEIRA *et al.* (2010). According to sieve analysis all samples were characterized as fine material (more than 90% passes through sieve #250 µm) but negligible fine content was found (less than 1% passes through sieve #63 µm). DMS used in this study were subjected to no treatment, washing or drying process. It was obtained from a disposal volume of 350000 m^3 extracted by a dredger and stockpiled for drying on open air for three months at the Port.

Concrete production considered type II Portland cement for maritime environment exposure. Four fractions of limestone raw aggregates: fine aggregates FA1 (0/2 mm) and FA2 (0/5 mm); coarse aggregate CA1 (5/12 mm) and CA2 (12/20 mm) from the plant of Amposta-Masdenverge (UNILAND) were used for concrete production. Physical properties of the aggregates are summarized in table 1.

Table 1. Density and water absorption capacity of aggregates (UNE-EN 1097-6).

Physical properties	***DMS***	***NS1***	***FA1***	***FA2***	***CA1***	***CA2***
Density(kg/dm^3)*	*2.63*	*2.65*	*2.7*	*2.69*	*2.7*	*2.7*
Absorption (%)	*1.0*	*0.4*	*0.4*	*0.7*	*0.8*	*0.4*

**Density on a saturated and surface–dried basis.*

A quantity of 4 kg/m^3 of polypropylene fibers (FORTA HIERRO®) with 54 mm length according to ASTM.C-1116-00 (2000) was incorporated in C3 concrete. The objective was enhancing the pavement flexural resistance and assessing DMS behaviour in the presence of plastic fibers. Polycarboxilate plasticizer (%P) was incorporated in the three concretes in order to achieve acceptable consistence for pumped casting.

2.2 Experimental program

Mass concrete exposed to marine air environment requires durability parameters which, according to UNE-EN 1744-1 specifications, define the maxim w/c ratio of 0.5 and the minimum cement amount of 300 kg for 1 m^3 of concrete. Chloride (Cl^-) and sulphate content (SO_3) are also limited in 0.05% and 0.8% of aggregates weight, respectively.

Mechanical tests such as compressive (UNE-EN 12390) and flexural strength (UNE-EN 14651) are required in order to guarantee the concrete designed resistance.

Figure 2. Cylindrical and prismatic samples subjected to mechanical tests.

LIMEIRA *et al.* (2010) presented acceptable compressive and flexural strength results in concrete made with DMS in comparison to control concrete. At the age of 28 days 30 MPa and 3 MPa were respectively achieved. Samples were subjected to standard vibration and moist curing in a humidity room at 21±1ºC and 95% of humidity.
Further research was developed by LIMEIRA *et al.* (2011) in concretes with 15% to 50% raw sand replacement by dredged marine sand from Barcelona’s Port. Partial results highlighted acceptable compressive strength results around 35 MPa to 40 MPa with 20% strength enhancement comparing to control mix. Flexural strength results around 4.5 MPa revealed slight however acceptable decrease (maximum of 10%) in some mixes comparing to control mix. Durability tests were also carried out as the volume of permeable pores and absorption (ASTM C 642-06, 2006), as well as the capillary absorption coefficient (UNE 83982) using cylindrical specimens with a diameter of 150 mm and a height of 150 mm, LIMEIRA (2011).

3. Conclusions

From this partial experimental program, some conclusions can be drawn. Considering the obtained physical properties, DMS is considered as very fine sandy sediment with any pollutant.
Preliminary tests performed on pastes and mortars revealed DMS feasibility as corrective sand rather than addition (LIMEIRA, 2011). DMS used in substitution of fine sand (0–2 mm) in different concretes has given appropriate mechanical properties comparatively to the control concrete C1.
Details and analyses of the mechanical concrete behavior have been reported by LIMEIRA (2011). For the concrete C3 some observations have been made about the influence of a higher plasticizer and/or reinforcement by fibers.
Finally all the carried out tests and results obtained suggest that DMS, a sandy dredged sediment studied can be successfully used as a fine aggregate for concrete production. It

is an acceptable material for construction of a harbor road pavement with concrete of 30 MPa.

4. References

ASTM C 642-06 (2006). *Standard test method for density, absorption, and voids in hardened concrete*.

ASTM C 1116-00 (2000). *Standard specification for fiber-reinforced concrete and shotcrete.*

CEDEX (1994). *Recomendaciones para la gestión de los materiales de dragado en los puertos españoles*. Ministerio de Obras Públicas, Transportes y Medio Ambiente. Madrid. 45 p.

COLIN D. (2003). *Valorization of fine dredging sediments in road techniques*. Ph. D Thesis, University of Caen, France, 147 p.

DUBOIS V., ABRIAK N.-E., ZENTAR R., BALLIVY G. (2008). *The use of marine sediments as a pavement base material*. Waste Management Journal, Vol. 29(2), pp 774-782. doi:10.1016/j.wasman.2008.05.004

KAMALI S., BERNARD F., ABRIAK N.-E., DEGRUGILLIERS P. (2007). *Marine dredged sediments as new materials resource for road construction*. Waste Management Journal, Vol. 28(5), pp 919-928. doi:10.1016/j.wasman.2007.03.027

LEVACHER D., COLIN D., PERRONI A.-C., DUAN Z., SUN L. (2006). *Recyclage et valorisation de sédiments fins de dragage à usage de matériaux routiers*. IX JNGCGC, Brest, pp 603-612. doi:10.5150/jngcgc.2006.058-L

LIMEIRA J., AGULLÓ L., ETXEBERRIA M. (2010). *Dredged marine sand as construction material.* XI JNGCGC, Les Sables d'Olonne, pp 877-886. doi:10.5150/jngcgc.2010.095-L.

LIMEIRA J. (2011). *The beneficial use of dredged marine sand as an alternative material for concrete.* Ph. D Thesis, Polytechnic University of Catalonia, 191 p.

LIMEIRA J., AGULLO L., ETXEBERRIA M. (2010). *Dredged marine sand in concrete: An experimental section of a harbor pavement*. Construction and Building Materials, Vol. 24, pp 863-870 doi:10.1016/j.conbuildmat.2009.12.011

LIMEIRA J., AGULLO L., ETXEBERRIA M., MOLINA D., (2011). *Mechanical and durability properties of concrete made with dredged marine sand.* Construction and building Materials, Vol. 25(11), pp 4165-4174. doi:10.1016/j.conbuildmat.2011.04.053

UNE 83982. *Determination of the capillary suction in hardened concrete*.

UNE-EN 1097-6: *Determination of particle density and water absorption*.

UNE-EN 1744-1. *Tests for chemical properties of aggregates. Chemical analysis*.

UNE-EN 12390. *Testing hardened concrete - Compressive strength of test specimens*

UNE-EN 14651. *Test method for metallic fibre concrete - Measuring the flexural tensile strength (limit of proportionality (LOP), residual).*

ZENTAR R., DUBOIS V., ABRIAK N.-E. (2008). *Mechanical behavior and environmental impacts of a test road built with marine dredged sediments*. Waste Management Journal, Vol. 52(6), pp 947-954. doi:10.1016/j.resconrec.2008.02.002