Local use of Usumacinta River sediments of Mexico for sustainable building materials and unpaved roads

Usages locaux des sédiments du fleuve Usumacinta du Mexique pour des matériaux de construction et des routes non-revêtues durables

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RÉSUMÉ

Le projet multidisciplinaire Val-Uses, financé par l'ANR et son homologue mexicain Conacyt, propose d'aborder la complexité du bassin du fleuve Usumacinta du Mexique en utilisant les sédiments comme terrain d'investigation.

La partie dédiée à l'ingénierie du projet, s'intéresse à la valorisation des sédiments mettant en avant la recherche de filières qui promeuvent une réutilisation écologique pour des usages locaux. Deux filières de valorisation répondent à ces exigences environnementales et sociales :
- La fabrication de briques crues renforcées par des fibres naturelles considérées comme déchets et la fabrication de briques cuites à base de sédiments.
- La réalisation de couches routières avec des sédiments pour des routes agricoles non revêtues.

Des expérimentations sur des murs-modèles sous sollicitations horizontales et sur des routes sans revêtement soumises aux passages de roues à l'échelle 1, ont démontré la faisabilité de ces filières de valorisations durables.

ABSTRACT

The multidisciplinary Val-Uses project, funded by the ANR and its Mexican counterpart, Conacyt, proposes to address the complexity of the Usumacinta River basin of Mexico considering the sediments as a field of investigation.

The engineering part of the project focuses on the recycling of sediments, highlighting the development of techniques that promote ecological reuse for local applications. Two recycling techniques meet these environmental and social requirements:
- The manufacture of raw bricks reinforced with natural fibres considered as waste and the manufacture of sediment-based fired bricks.
- The production of road layers with sediments for unpaved agricultural roads and pathways.

Experiments on model walls under horizontal loading and, on unpaved roads under wheel traffic at a scale of 1, demonstrate the feasibility of these sustainable recycling methods.

KEYWORDS

Beneficial uses, Usumacinta River sediments, sediment-based crude and fired bricks, sediment-based road layers, masonry walls, unpaved road pilot.

1 CONTEXT OF THE STUDY

The Val-Uses project involves the detailed analysis of Usumacinta River sediments for local applications. The engineering part of the research project is integrated with the social and environmental context and raises the question of eco-friendly recycling of sediments and beneficial uses of sediments while referring to present and past uses in the interest of the regional populations of the basin.

The main objective is to use the sediments on the one hand as a renewable resource, in the case of dredged sand extraction, and on the other hand as an alternative material (fine sediments) that preserves natural resources. Sustainable sediment management requires research and analysis of the main potential ways of reusing the sediments of the Usumacinta River at the local level. First, this requires in-depth knowledge of sediment behavior at different spatial and temporal scales.

The use and/or recovery of the sediments, as a support material for these usages, must be managed reasonably and sustainably, without having a negative impact on the environment. These usages must be profitable to the local community by offering them sustainable and decent beneficial uses. Therefore, the management of river sediments must satisfy the strict environmental criteria, and also ensure the renewability of this natural resource. The location for the use must be in the proximity of resources (sediments) to limit transport and consequently greenhouse gas emissions.

The mineralogical, physiochemical, rheological and hydro-mechanical characterization of the sediments constitutes a database needed for the identification and pre-selection of potentially beneficial uses. Once collected, the characteristics of the sediments and their suitability for different applications were defined by their identity card (Djeran-Maigre et al, 2020). The various parameters of this identity card led to the exploration and selection of possible local beneficial uses: (1) manufacturing of bricks: from fired bricks to green bricks reinforced with local or non-local natural fibers waste and (2) construction of unpaved roads with low bearing capacity.

2 MASONRY WALL MODELS MADE WITH SEDIMENT-BASED BRICKS

One way of locally using sediments is the construction of lightweight artisan or agricultural buildings whose envelope consists of non-load-bearing walls. To study the behavior of these walls, small-scale pilot walls have been built at a laboratory scale using Usumacinta River sediment bricks. Bricks used are either limed bricks (lime added to sediments), or fibers reinforced crude bricks (sediments mixed with short natural fibers) (Hussain et al. 2021) or fired bricks. The mechanical properties of the different materials used to design the walls to be tested, *i.e.* bricks and mortars, were determined. Pilot walls with different geometries are tested in a horizontal plane to verify their behavior and durability considering the local seismicity. The walls built with Usumacinta River sediments-based bricks show the characteristics to classify these bricks as an eco-friendly building material that satisfies the needs of the local population (figure 1-1).

3 UNPAVED ROAD STUDIES WITH SEDIMENTS-BASED LAYERS

Roads, bike and pedestrian paths, agriculture and local services routes are mostly unpaved in the surrounding areas of the Usumacinta River. Therefore, another possible beneficial use of sediments is the construction of unpaved roads with sediment sub-layers. Artificial soils with mechanical characteristics close to those of limed sediments were used for full-scale experiments by reproducing traffic in field conditions: traffic levels and vibrations induced in roads. An economical and efficient way to make soils suitable for road use is the use of lime for a solidification/stabilization effect. The study of the behavior of sediments incorporation into road layers concerned the degradability of full-scale unpaved roads under wheel load and the analysis of the combined effect of traffic cycles and hydromechanical stresses on surface deformation of compacted soils (figure 1-2). Laboratory tests were conducted on a full-scale pilot road with a gravel sub-base layer supporting either non-stabilized or stabilized soil layers. These layers under traffic loads were tested and the behaviors were compared. This kind of experiment performed on a traffic simulator makes it possible to apply a normal unidirectional load corresponding to a loading on site acting on the half-axle.

4 CONCLUSIONS

The results obtained from the pilot wall tests are very promising: the tested walls behave mechanically as expected according to their geometry and the strength of their components, bricks and mortars. This work demonstrates that non-load-bearing walls can be built with bricks manufactured from Usumacinta River sediments. Furthermore, the sediment material is substantially reusable and can be recycled in its entirety. Moreover, since transport is minimized in this case of local construction, bricks made from Usumacinta sediments have all the properties to be considered as environmentally friendly building materials.

The construction of unpaved roads or service roads for agriculture or even for bike and pedestrian pathways can be developed with rational use of sediments from the Usumacinta River. And it is important to mention that throughout the life cycle of the road, maintenance can be provided and carried out at any time: repairs could be done with the same original material, namely, the sediments. From an environmental point of view, the sustainability of this kind of unpaved road structure is established.

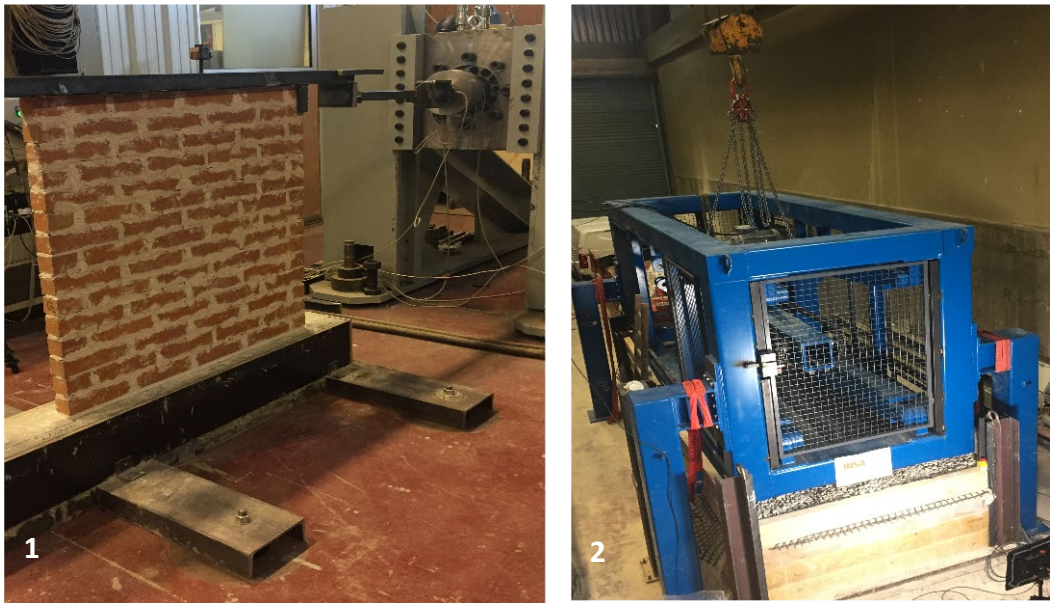

Figure 1 : Masonry wall built with sediment-based bricks to be tested (1) ; unpaved road pilot with traffic circulation simulator (2).

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