A Rheological Fuzzy Model for Lime Plasticity and Mortar Consistency

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Abstract:
This paper is concerned with a fuzzy model developed for describing the rheological properties of lime pastes and mortars. We have identified the physical parameters on which the flow properties of these materials depend, and whose complex interrelationships make it difficult to model the phenomena using a traditional approach. The basic notions of fuzzy modelling are described, a technique which enables different kinds of variables and other knowledge elements to be handled in a formal context that can be easily computerized. Applying the Fuzzy Approximation Theorem we can develop a model irrespective of whether the correlation functions are expressed in explicit analytical form or not. The definitions of the fuzzy sets for the different variables are provided which, together with IF/THEN rules comprise the knowledge base of the model. The model is then applied to determine the plasticity of lime pastes and consistency of lime-based mortars using ordinary fuzzy inference mechanisms.

Zusammenfassung:
Dieser Artikel befasst sich mit einem Fuzzy-Modell, das zur Beschreibung der rheologischen Eigenschaften von Kalkpasten und Mörtel entwickelt wurde. Wir haben die physikalischen Parameter identifiziert, von denen die Fliesseigenschaften dieser Materialien abhängen und deren komplexe Beziehungen es schwierig machen, die Phänomene mit einem herkömmlichen Ansatz zu modellieren. Die grundlegenden Begriffe der Fuzzy-Modellierung werden beschrieben, die eine Methode ist, die verschiedene Arten von Variablen und Wissenselementen in einen formalen Zusammenhang bringen kann, der einfach programmiert werden kann. Durch Anwendung des Fuzzy-Näherungstheorems können wir ein Modell entwickeln unabhängig davon, ob die Korrelationsfunktionen in expliziter analytischer Form ausgedrückt sind oder nicht. Die Definitionen des Fuzzy-Satzes für die unterschiedlichen Variablen werden gegeben, die zusammen mit IF/THEN-Regeln die Wissensbasis des Modells bilden. Das Modell wird angewandt, um die Plastizität von Kalkpasten und die Konsistenz von auf Kalk basierten Mörteln mit Hilfe gewöhnlicher Fuzzy-Interferenzmechanismen zu bestimmen.

Résumé:
Cet article s'intéresse à un modèle indistinct développé afin de décrire les propriétés rhéologiques de pâtes et de mortiers de chaux. Nous avons identifiés les paramètres physiques qui influencent les propriétés d'écoulement de ces matériaux, et dont les inter relations complexes rendent difficiles la modélisation des phénomènes effectuée avec une approche traditionnelle. Les notions de base de la modélisation indistincte sont décrits: c'est une technique qui permet de manipuler différent types de variables et d'autres éléments de connaissance, dans un contexte formel qui peut être facilement implémenté dans des calculs numériques. En appliquant le Théorème d'Approximation Indistincte, nous pouvons développer un modèle indépendamment du fait que les fonctions de corrélation sont exprimées dans une forme analytique explicite ou non. Les définitions des ensembles indistincts pour les différentes variables sont fournies ce qui, en même temps que les règles SI/ALORS, constitue la connaissance basique du modèle. Le modèle est alors appliqué à la détermination de la plasticité des pâtes de chaux et de la consistance de mortiers basés sur de la chaux, en utilisant des mécanismes ordinaires d'hypothèse indistincte.

Key words: consistency, fuzzy modelling, lime, mortars, plasticity

1 INTRODUCTION

The ability to flow under the action of external forces has a decisive influence on the overall performance of materials made up of a dispersion with a high granular solid content of broad size range and a liquid phase, prepared and emplaced in a "fluid" state (e.g. pastes, mortars and concretes, with lime or cement binders).

In particular, there is now a revival in the use of lime, a material employed since antiquity, for the restoration of historic buildings where it has to comply with fairly demanding specifications. The rheological qualities of lime have been known for some two thousand years, as documented by Vitruvius in his treatise on the art of Roman architecture [1 – 3]. The study of the rhe-

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The presence of air in the form of submillimeter size bubbles acts as an important plasticizer of mortar (the bubbles can be naturally entrapped or deliberately incorporated by means of air entraining agents for thermal insulation, freeze/thaw resistance or to counteract the effects of salt crystallization). Fuzzification of the air (bubble) content is shown in Fig. 11. Table 3 shows the rules (n = 79) for determining mortar consistency.

This block of rules indicates, for example, that whatever the plasticity of the lime paste, for large contents of unfavourable sand type and in the absence of an air entraining agent, mortar consistency is bound to be very poor. Conversely, good mortar consistency requires a high quality putty with high, average or even poor plasticity if admixed with adequate amounts of air entraining agent and the appropriate proportion of sand with good rheological properties.

6 CONCLUSIONS

The rheological properties of the pastes and mortars widely used in civil engineering and for the restoration and conservation of historic/artistic monuments decisively affect the ultimate properties of the work performed. However, to date the characterization of these materials suffers from a large dose of empiricism, uncontrolled subjectivity and, as a result, ambiguity.

The peculiar nature of these "fluids", which contain large concentrations of solids with a grain size of up to a few millimetres, has made their physical characterization impossible. The persistence of qualitative concepts such as plasticity and consistency also in European Norms, is nonetheless justified by the all-inclusive qualitative nature of these terms.

We have provided a quantitative description of plasticity and consistency and established a correlation with the numerous variables involved, adopting a fuzzy logic approach for modelling the phenomena. The advantage of this approach is that it allows to rationally handle in mathematical and computerizable terms the entire knowledge base available, albeit within the framework of soft-computing/approximate reasoning.

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