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Stabilization of unfired earth for buildings using lime and polymeric dispersants

Wall construction in raw earth dates back, in various forms, for several thousand years. Raw earth is used in buildings for loadbearing walls, as well as a cladding for both interior and exterior finishing and for interior floors.

In all these applications, the raw earth clayey material needs to be stabilized against humidity and abrasion. Our approach has been to use lime in order to reduce the plasticity and the water demand of the raw earth, along with a polymeric dispersant to deflocculate the clay particles and enhance their pozzolanic reactivity.

In the short term, the addition of lime to aqueous sodium-montmorillonite-dispersions results in an equilibrium shift towards the calcium form of the montmorillonite. This greatly influences the crystalline swelling behaviour of the montmorillonite and the yield point of its dispersions. The raw earth is further deflocculated through the use of a polymeric anionic dispersant. Thus, the surface reactivity of the clay particles is strongly enhanced.

In the long-term, the continuous dissolution of clay minerals in the presence of lime leads to the cementation of the materials by the formation of hydration products. The cementation has proceeded after one to two months as far as the surfaces of the clay mineral-lime aggregates were completely covered with reaction products. Testing is underway with the aim to verify the possibility to cast raw earth into molds without the need for mechanical compression, and to determine the mechanical properties of the materials, both as a compressive strength and as shrinkage and micro cracking.

In the present work, preliminary results on the characterization of two different earths are reported. Different series of samples has been prepared: the reference series and the series with lime (5%wt). All the samples are fully characterized by means of X-ray powder diffraction at different time of aging.

Experimental and Discussion

Two different earth samples were taken into account: sample T1 and T3. The two raw materials were first characterized with some simple sensitive analyses and field tests in order to identify to which category the soil sample belongs (i.e. gravely, sandy, silty, clayey or combined soil, i.e. sandy clay or clayey sand, etc.). The results of sensory tests are reported in table 1. The two earth samples appear quite different starting from a first visual analysis; the first one, T1 being grey while T3 is brown. In the touch test, a dry and wet soil is rubbed between the fingers. Usually sands have a rough feel and lack cohesion, dry silt is less rough than sand and shows some cohesion when wet. Dry clods indicate the presence of clay lumps which becomes very sticky or greasy when wetted. T1 shows the presence of hard flakes hardly breakable, while T3 has the presence of some lumps easily disintegrating. Also the smell test delivers differences between the two samples, even though both samples indicate the absence of organic matter.

Table 2 shows the results of the field tests. The adhesion test evidences that both samples don't show the presence of soil, i.e the knife is clean, indicating the presence of clay and a variable minor amount of sand. The cigar test shows different result for the two samples. This test is usually used to determine the relative grading of the soil and its suitability for use as a construction material. Some amounts of damp soil is mixed and then rolled to produce a cigar with a diameter of about 15 mm. The cigar is then fed forward out of an edge of a table and the length at which it brakes is measured. This length is an indication of the sand, silt and clay content. If the length

Fig. 1 a) cataloguing earth colour with Munsell table; b) Munsell table; c) earth biscuit ;d) jar sedimentation; e) knife test; f) water test; g) cigar test

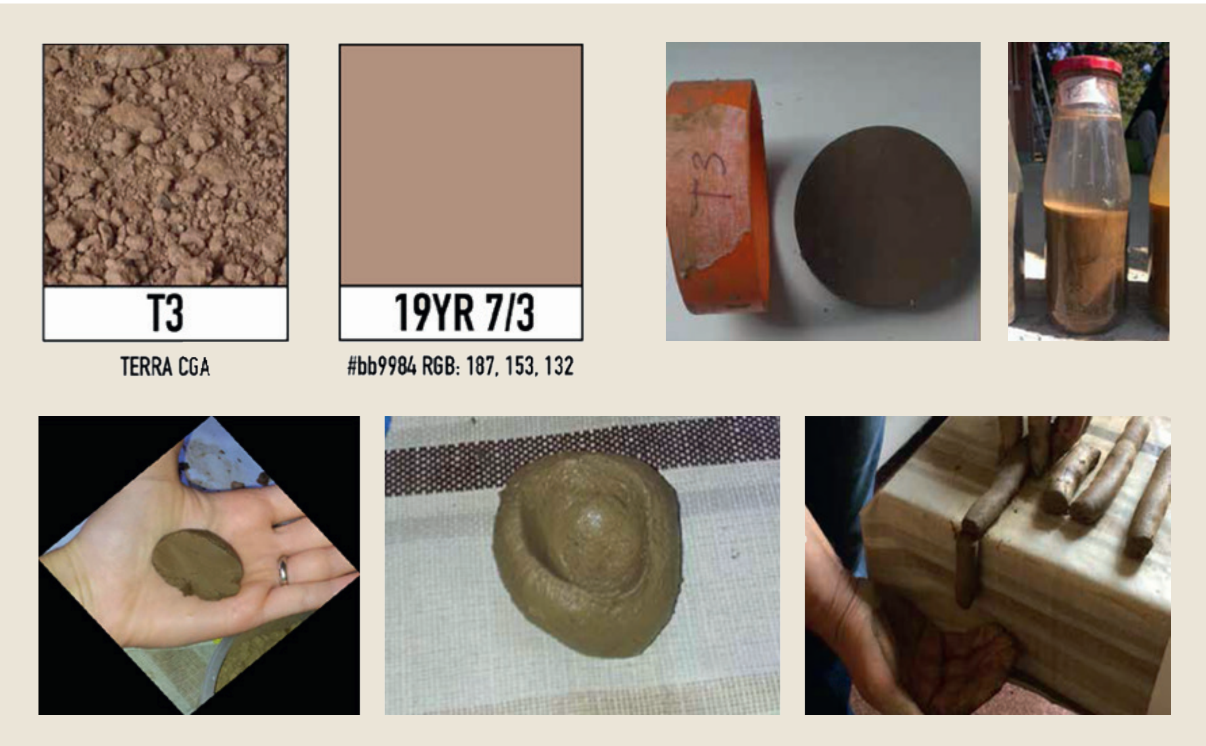


Fig. 2 a) cataloguing earth colour with Munsell table; b) Munsell table; c) earth biscuit ;d) jar sedimentation; e) knife test; f) water test; g) cigar test

Table 1: Results of sensory tests of sample T1 and T3

Test	Sample T1	Sample T3
Colour	Grey ref. Munsell Table - Pantone P169-5 U	brown ref. Munsell Table - Pantone P19-4/5 U
Touch	hard flakes hardly breakable	lumps easily disintegratin
Smell	earthy	fine particles
Taste	neutral taste	neutral taste
Hearing	presence of flakes	sand

Table 2: Results of fied test of sample T1 and T3

Test	Sample T1	Sample T3
Adhesion test	Clean, only some amount of clay	clean
Cigar test	46 cm 39 cm. Too much clay	10 cm; 10 cm; 10 cm; 10 cm. Good mixture
Water absorption	Water remains, absorbed after 2h 30’	Water remains, absorbed after 2h 30’
Jar sedimentation	after 24 h some clays still in water	After 24 h no clays
Biscuit test	Presence of breaks, shrinkage 1.035%	Absence of breaks, shrinkage 1.94%

is below 5 cm, the sample has high amount of sand, between 5-15 cm the sample has a good mixture between sand and clay, and a length greater than 15 cm indicates too much clay. T1 shows higher content of clay compared to T3. For the water absorption test, an imprint of the thumb is made on a ball of the soil in order to obtain a small depression in it, which is filled with water to evaluate the time of absorption. For both samples the water is absorbed very slowly, in 2 hours and 30 minutes, indicating a correct mix between clay and sand for both samples. Then, for the biscuit test, a smooth paste is made from the soil removing all gravels, which is then shaped into a mould of 5 cm of diameter and 2 cm of height, let dry and observed for shrinkage or cracks and then broken to observe how hard it was. If the biscuit cracks or detaches from the mould it contains more clay, as if it is very hard to break; if it breaks easily and can be crumpled between finger than it has good sand-clay proportion; if it breaks and reduces to powder then the soil has more sand or silt. Also this test shows that sample T1 has the presence of more clay with respect to T3. The last examination is the sedimentation test; it is a simple field test, which is useful to determine the approximate amount of fine gravel, sand, silt and clay. A transparent jar is used, it is filled for about 2/3 with soil and then water is added. The jar is sealed and the water is allowed to completely soak into the soil. The jar is then shaken for 2 minutes, left to stand for 1 hour, shaken for another minute and then placed on a flat surface. Approximately 45 to 60 mingutes later, the fine gravel, sand and silt layers should be clearly visible. After a further 24 hours the clay particles should have also settled out of suspension. Without disturbance, the height of each layer should then be measured to give relative ratios between fine gravel + sand to silt + clay. The difference between the two samples is again related to the presence of fine particles. All these tests are reported in figure 1 and 2 for T1 and T3 respectively.

After the sensory and field test some laboratory test were performed. First of all, the particle size distribution was measured according to CEN ISO/TS 17892-4, which also measures the humidity of the soil. The samples were first weighted and then dried in an oven for 24 hours at 105°C and then the amount of water was determined. Successively the sedimentation test was performed in order to have more precise information about the composition of the two samples. The results are reported in figure 3. From the comparison of the two samples, it can be observed that T1 show a higher amount of “clay fraction”; indeed in T1 it is about 44% while in T3 it is 20%. The two soils were tested for Atterberg Limits according to UNI CEN ISO/TS 17892-12:2005. The liquid limit, the plastic limit and the plasticity index are related to both mineralogy and the amount of clay present in the soil sample. The results are reported in figure 4. The results show that sample T1 shows a plasticity index greater than sample T3. These results are in good agreement with the results obtained by mix-

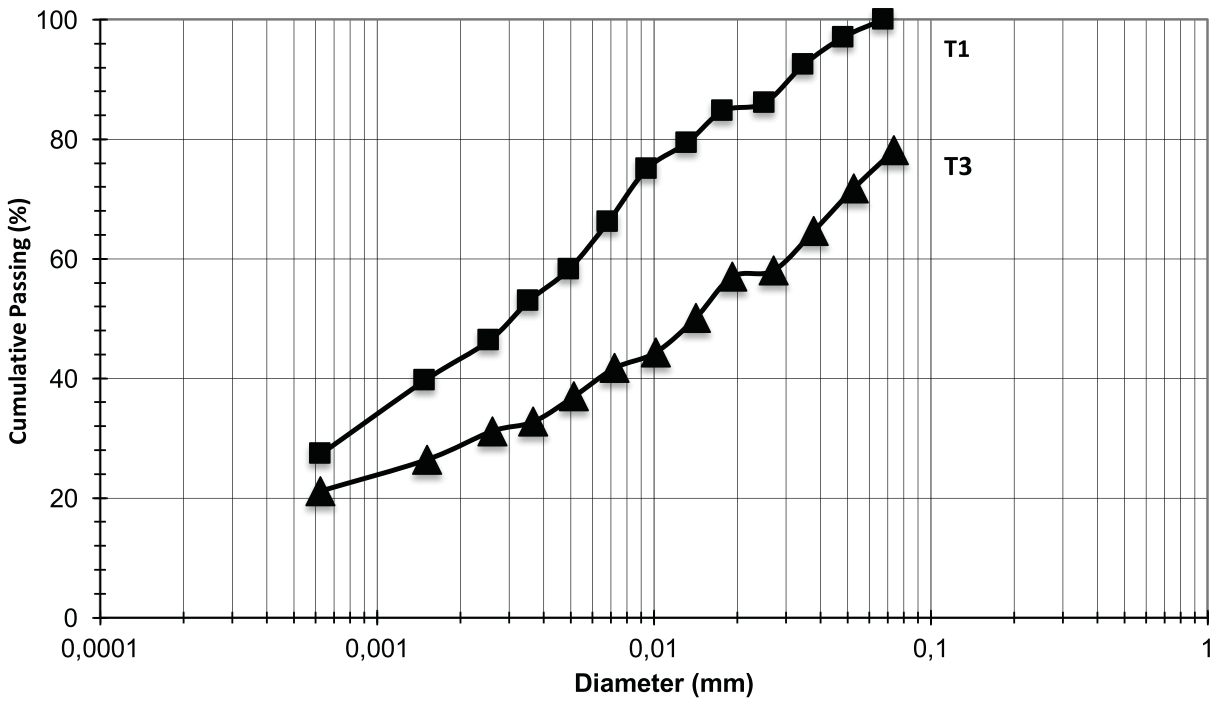


Fig. 3 Granulumetric curves of sample T1 and T3

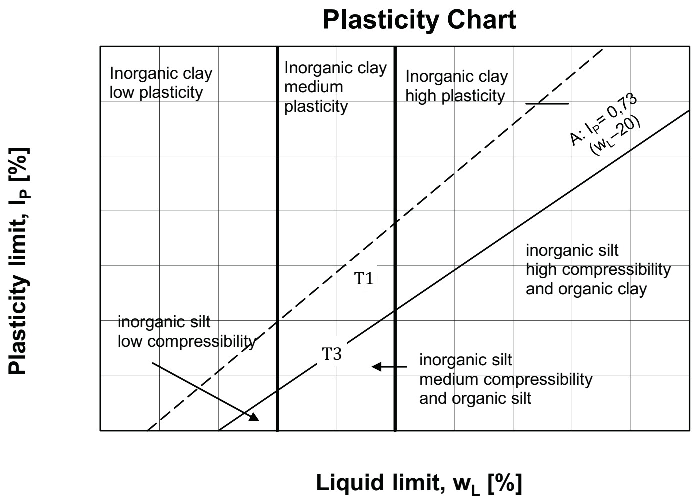


Fig. 4 Plasticity chart for sample T1 and T3

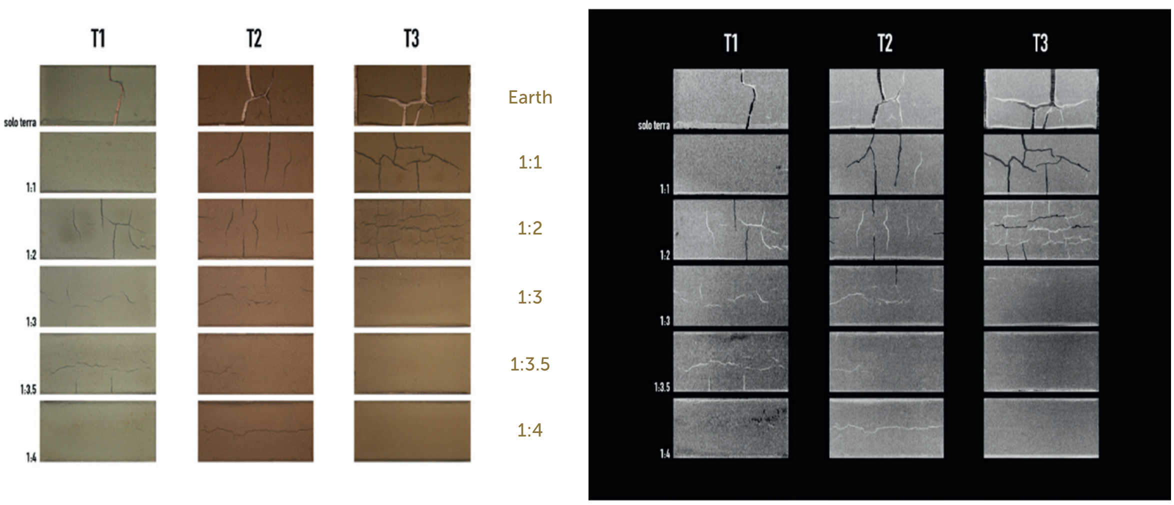


Fig. 5 Photographs of hollow flat tiles prepared at different ratio of earth and sand for cracking tests

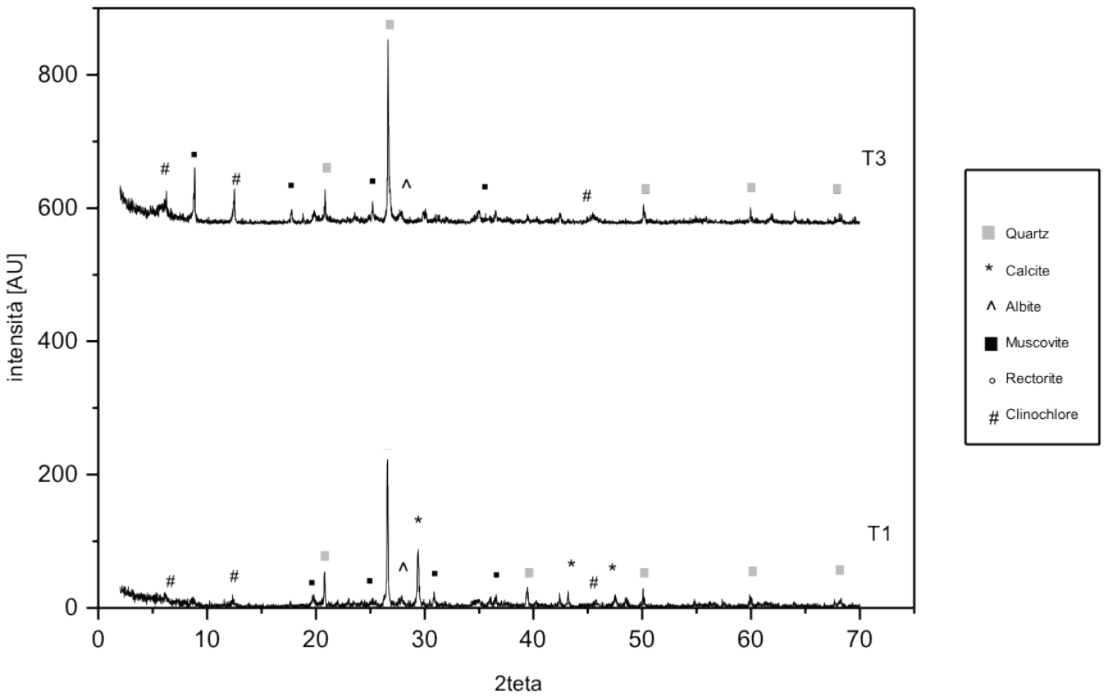
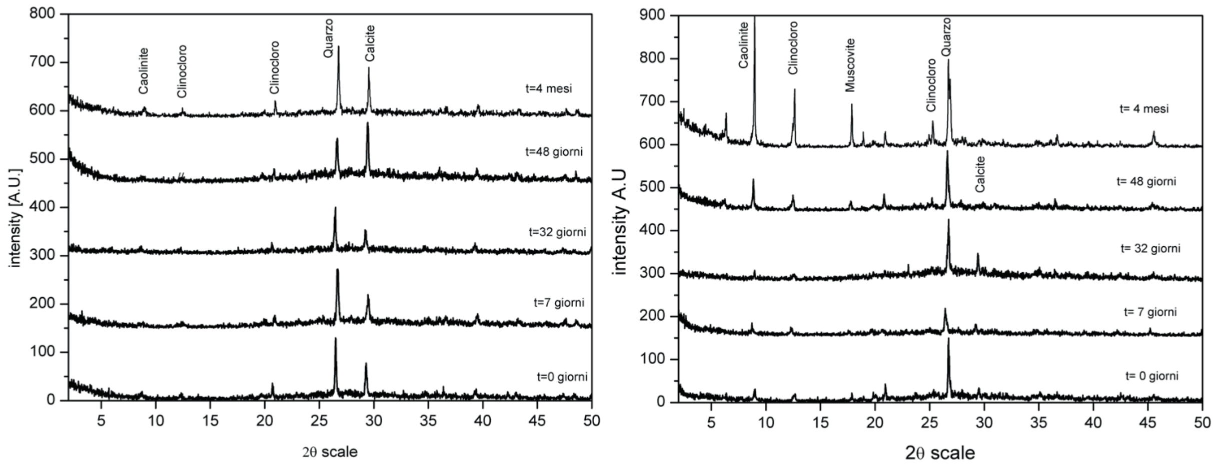


Fig. 6 XRD patterns of samples T1 and T3



Figs. 7 + 8 XRD patterns of samples T1 (left) and T3 (right) and dolomite at different times of aging

ing the two earth samples with different amount of sand. For a soil with a higher plasticity index, a higher amount of sand is needed in order to obtain a mortar which dries without cracks; figure 5 reports different samples prepared with increasing ratio between the earth and sand. It can be observed that sample T3 shows a good result starting from a ratio earth:sand of 1:3 while sample T1 that needs a ratio earth:sand of 1:4. The two samples were characterized by means of X-ray diffraction in order to have more information about the mineralogical composition. In figure 6, the two diffractograms of the two samples are reported. T1 and T3 show some differences in the composition. Both of them show the presence of quartz and muscovite. In T1 there is the evidence of calcite, while T3 shows clinochlore, illite and feldspate. A set of different samples, containing the same amount of lime, i.e. 5%wt/wt, but from different sources, i.e. dolomitic lime, lime putty and lime produced as a by product of acetylene production, were prepared. The stabilized samples were studied at different time of aging in order to assess the different reactivity of the two samples, T1 and T3, with respect to the different lime used. In figure 7 and 8, XRD patterns of the different series (T1 and T3, respectively) are reported. It can be observed that for series of samples prepared with T1 there is no evidence of pozzolanic reaction between earth and lime even if after four months; while analyzing series prepared with sample T3, it can be observed the presence of new phases, due probably to some reactions between lime and earth. Particularly, portlandite peak is not present, meaning that lime is reacting to give new phases, i.e. tobermorite and calcium aluminum sulfate hydrate (Afm).

Conclusions

In the present work, some preliminary analyses were made on two earths sample, in order to fully characterized them and use in future works for loadbearing walls, as well as a cladding for both interior and exterior finishing and for interior floors. The preliminary analyses reveal that:

1. Sample T1 is an inorganic clay of medium plasticity
2. Sample T3 shows behaviour between inorganic clay of medium plasticity and an inorganic silt of medium compressibility.

All these results were confirmed by XRD analyses. Moreover, the effect of stabilization with different lime was studied. It can be observed that when T1 is mixed with lime there is no evidence of pozzolanic reaction between earth and lime even if after four months; while T3 evidenced the presence of new phases, due probably to some reactions between lime and earth. Particularly, portlandite peak is not present, meaning that lime is reacting to give new phases, i.e. tobermorite and calcium aluminum sulfate hydrate (Afm).