Preliminary Investigation into Mechanical Properties of Clay Reinforced with Natural Fibres

P. Peetsalu[1,2], J. Resev[2], A. Ruus[2], A. Menind[3], Jaan Kers[1], S. Sepper[1] and J. Olt[3]

[1]Department of Materials Engineering, Tallinn University of Technology
[2]Tartu College, Tallinn University of Technology
[3]Institute of Technology, Estonian University of Life Sciences,
56 Kreutzwaldi Str., EE51014 Tartu, Estonia
e-mail: jaan.kers@ttu.ee, andres.menind@emu.ee

Abstract. Nowadays natural materials are popular and favoured in civil engineering. At the same time it is important to use renewable and local materials which have low CO_2 production. One of these materials is clay reinforced with natural fibres. For production purpose it is necessary to find the natural fibres which have suitable properties and can be grown in large amounts. This kind of fibre is flax, which produces a strong fibre. The article focuses on flax as a reinforcing natural fibre in clay which can be used for walls and undercoat plasters. Flax is milled to fractions with different length and mixed with clay, sand and water. Dried clay mix cube's compressive strength is measured. Finally the best fraction as for flax length and amount is suggested for future experiments to find out the best fraction of fibres for clay with good compressive strength.

Key words: Undercoat plaster, natural fibres, flax, clay fibre fraction size distribution, compressive strength

INTRODUCTION

Earth building is an ancient construction method, rarely in use in contemporary architecture. There are many methods for building with earth. The simplicity of construction and possibility of achieving good construction quality with minimal costs gives hope that this method can provide answers to the big questions of our time (Sargentis et al., 2009).

Clay can be used as binder component in walls built of adobe, cob, rammed earth (Minke, 2006), and/or plaster. Reinforcement interacts with the soil to produce a composite material in which the roots are fibers of relatively high tensile strength and adhesion inherent in a matrix of lower shear strength soil (Huat et al., 2005).

Clay has a good reputation of being an indoor relative humidity regulator due to its good and fast moisture absorptivity (Mauring et al., 2009).

The notion non-industrial materials in building is linked to local materials which makes it worthy of interest again (Morel et al., 2001), owing to the need to reduce the energy consumption of the building industry. The concept of non-industrial building materials means materials being manufactured using a simple, quick process with low embodied energy and raw materials from the site or the vicinity.

The mechanical properties of construction materials depend on several factors, including the characteristics of the raw material and the manufacturing process. This manufacturing process is generally evaluated by measuring dry density (Morel et al., 2007).

The dry density of non-industrial products varies more when moulding water content is under 22% (Kouakou et al., 2009). This happens due to the fact that manually moulded samples are not homogeneous. At the same time the most important parameter for earth materials – compressive strength – is bigger in samples with higher dry density.

MATERIALS AND METHODS

Sand and clay

Dried screened sand is used in this study. The manufacturer of the sand is AS ′Silikaat′ in Estonia. The sand is extracted from the Männiku quarry. The fraction of the sand is 0.63-2 mm (fineness module is 2.7-3.7 and fine particle 0.063 mm content is less than 5%). A photo of the sand is shown in Fig. 1. Ground clay is used as a plastering agent. The manufacturer of the clay is SIA ‘Ceplis’ in Latvia. The colour of the clay is deep orange-red. A photo of the clay is shown in Fig. 2.

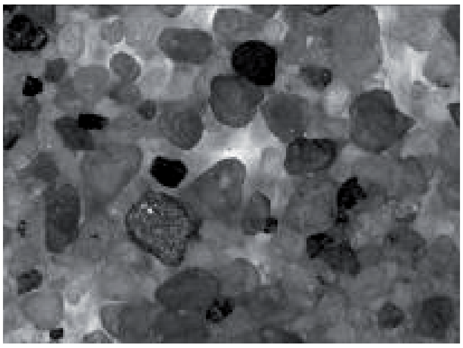

Fig. 1. Photo of the sand used in this study.

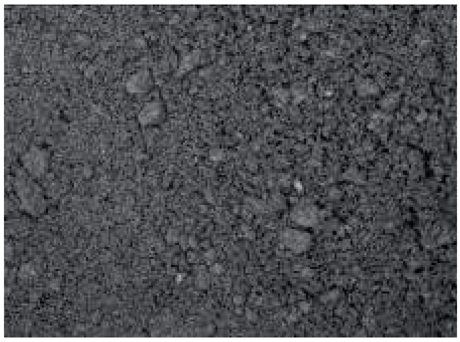

Fig. 2. Photo of the clay used in this study.

Particle size distribution of clay is shown in Fig. 3. Laser light scattering method (particle size measurement instrument: Fritsch Analysette 22) shows that the average particle in the clay content is 6 µm.

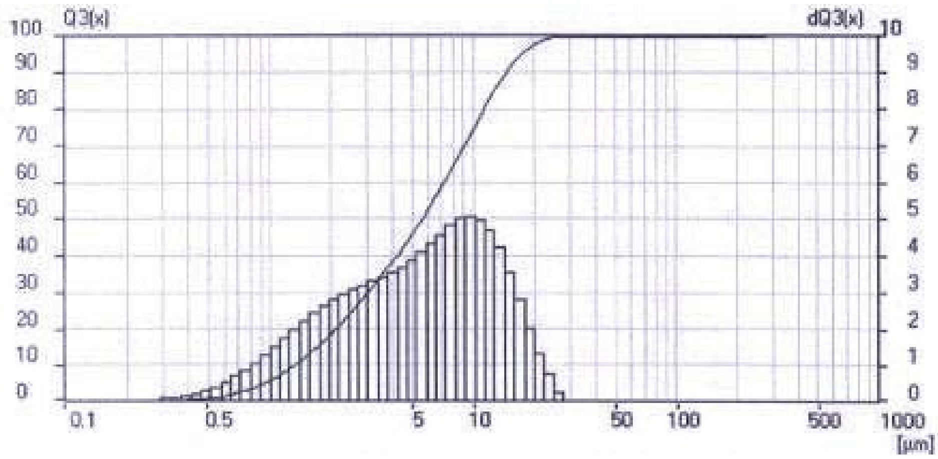

Fig 3. Particle size distribution in clay.

Fibres

Natural fibres used in this study were flax fibres (*Linum usitatissimum*). In this study the fibres were cut in 5, 30 and 50 mm long pieces as shown in Fig. 4 and added to the clay and sand mixture. Flax fibres are hollow tubes consisting primarily of cellulose. Fig. 5 shows the fibres through stereo microscope.

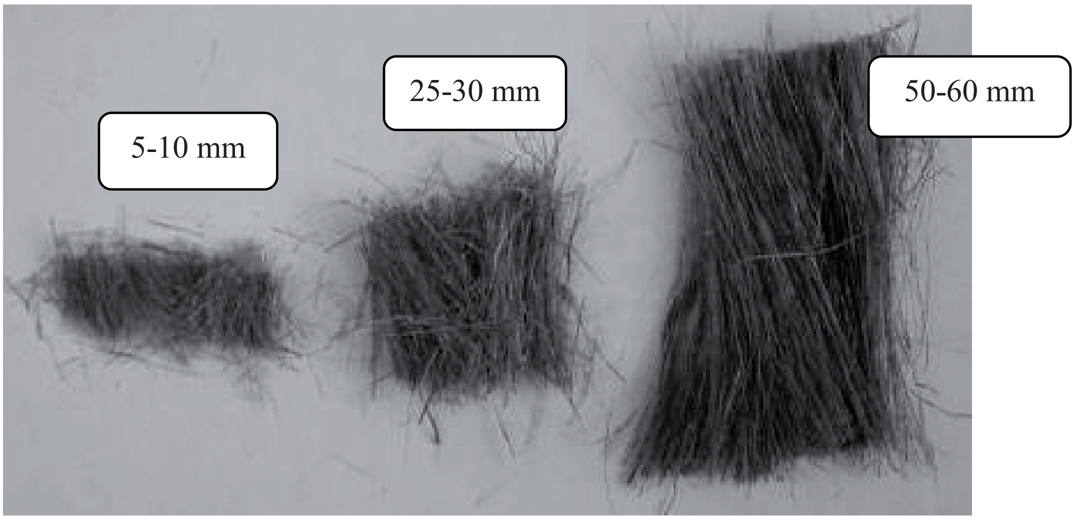

Fig 4. Different lengths of fibres.

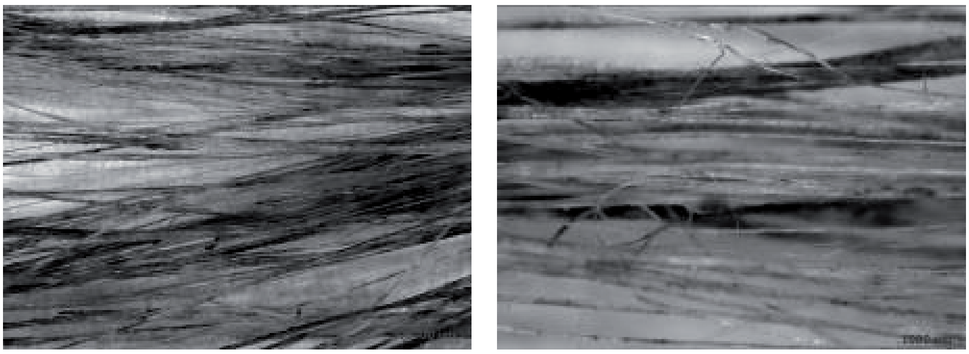

Fig 5. Flax fibre observed through stereo microscope.

Preparation of samples

Clay and sand were mixed with a whisk. The volume ratio was 1:3. The optimum volume of water (20%) was added and stirred until the mixture was homogeneous. The mixture of clay and fibre was then divided into four portions, into three of which were added flax fibres, mixed by hand (there was 14 g fibre in each cube).

Cubes with dimensions 10x10x10 cm were produced. Three cube specimens were prepared for each test. A total of 12 cubes were prepared (three of them were non-fibrous samples). After a three day long drying period the reinforced clay was removed from the moulds and turned upside down to evaporate water from every part at the same rate. The total drying period lasted for7 days. The specimens were dried in lab at room temperature (25°-28°C).

RESULTS AND DISCUSSION

Testing system INSTRON 8516 was used to determine the compressive strength (Fig. 6). Specimens were compressively loaded at a rate of 5 mm min^{-1}. The specimens were in a plastic bag to collect specimen particles for next investigations.

Fig 6. The compressive test.

The results of the experiments show that the compressive strength depends on the length of flax fibres. The results of the compressive test are shown in Table 1. The non-fibrous specimens had the lowest compressive test results (0.55 MPa). Adding fibres increased the compressive strength. Fibre length 30 mm gave the best compressive test results (0.83 MPa). Compared to non-fibrous specimens, compressive strength increased 50%. The strength results of fibre with the length of 50 mm were lower than those of fibre with the length of 30 mm.

Table 1. Compressive test results

		Specimen label	Maximum Load (N)	Compressive Strength (MPa)
	2	II non fibrous	5,205	0.50
	3	III non fibrous	5,759	0.60
Mean			5,482	0.55
	4	I fibre length 5 mm	6,735	0.70
	5	II fibre length 5 mm	6,633	0.70
	6	III fibre length 5 mm	5,941	0.60
Mean			6,436	0.67
	7	I fibre length 30 mm	8,180	0.80
	8	II fibre length 30 mm	10,421	1.00
	9	III fibre length 30 mm	7,464	0.70
Mean			8,688	0.83
	10	I fibre length 50 mm	7,888	0.80
	11	II fibre length 50 mm	7,586	0.80
	12	III fibre length 50 mm	7,048	0.70
Mean			7,507	0.77

The compressive diagram is shown in Fig. 7. The test was stopped when maximum load decreased 40%. Testing of the non-fibrous specimen after the maximum load had been achieved showed that the load decreased rapidly and compressive extension after cracks formation was 3-4 mm. Adding fibres with 5, 30 and 50 mm length helped to prevent the spread of cracks significantly. The load decreased after cracking more slowly and the compression extension was bigger.

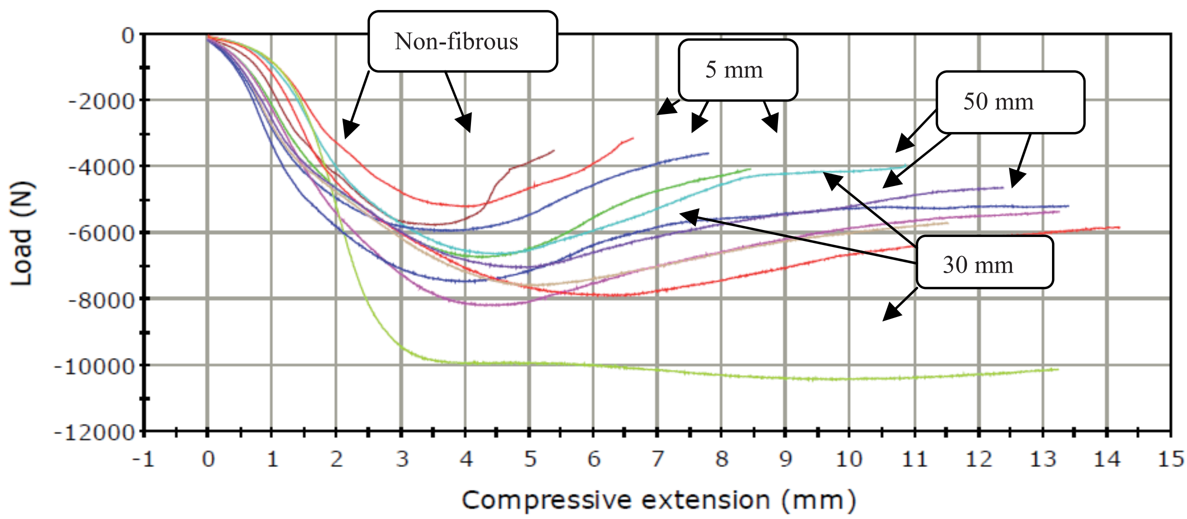

Fig. 7. Compression diagram.

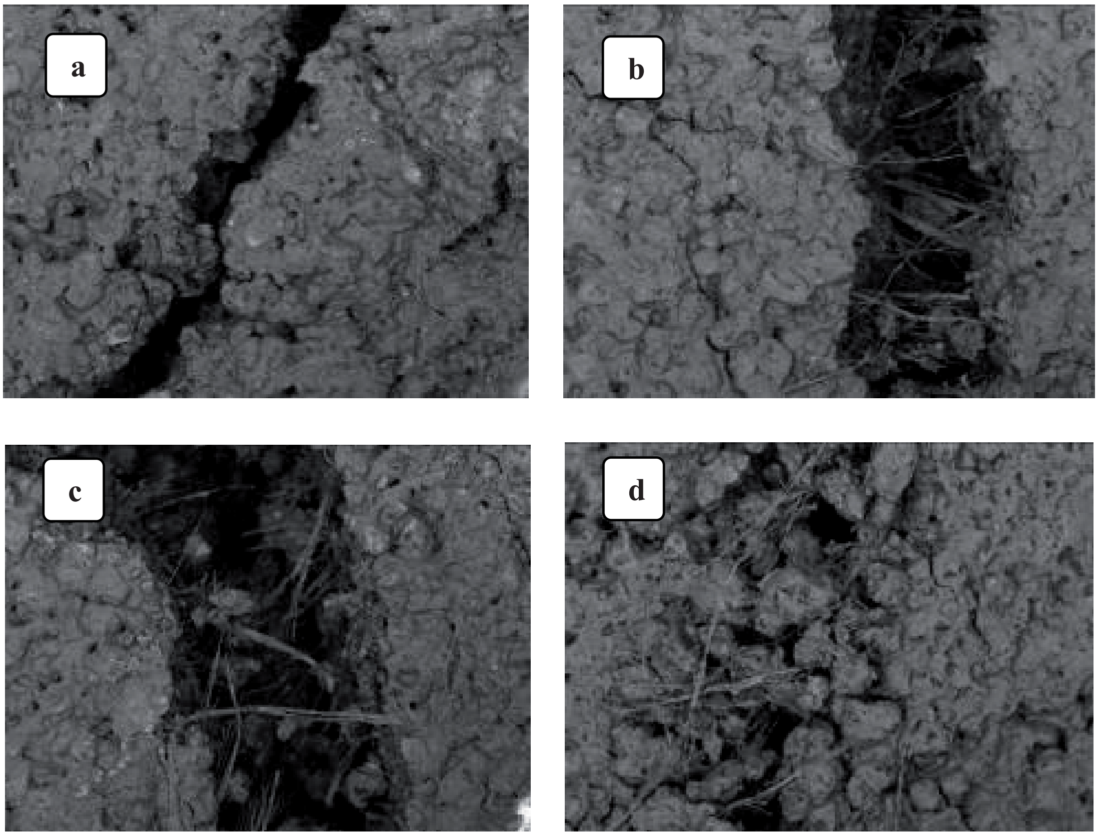

Fig. 8. Photos of cracks generated during the compressive test: a) non-fibrous, b) fibre length 5 mm, c) fibre length 30 mm, d) fibre length 50 mm.

Crack size is related to compressive extension, the presence of fibres and exerted load. Fig. 8 shows the cracks, generated during the compressive test. The reason why the crack of a non-fibrous specimen is the smallest is that after cracking the loads were low. Fibres of 5 mm in length were pulled out of the matrix (Fig. 8 b) while fibres of 30 mm in length cracked during the test. Fibres of 50 mm in length were not distributed homogenously in the matrix and caused lower compressive strength than fibres of 30 mm in length. As it can be seen in the compression diagram, the strength of specimens was retained at extension up to 13 mm. Behaviour and properties of clay mix with longer fibres in the cracks is useful when cracks in the wall need repairing as the fibres act like reinforcement for the new mix.

Based on compressive strength results and ability to obtain uniform mixture of clay and fibre, the 5-30 mm fraction is good for a new plaster for walls and undercoat. For future experiments it is necessary to test fibres between 5 and 30 mm with different length distributions.

CONCLUSIONS

1. Flax fibres used in this study increase compressive strength and prevent the spread of cracks.
2. Compressive tests give the best results with using specimens with 30 mm fibre length which ensure the highest compressive strength.

3. Compressive strength is similar when using 5 mm or 50 mm long fibres.

4. Fibres with the length of 30 mm were broken after the compressive test and 5 mm fibres were pulled out of the matrix, which is visible in the photographs. That kind of behaviour is of great help when clay plaster or a wall needs repairing, as the fibres in the cracks act like reinforcement for the new repairing mix.

5. Fibre of 50 mm in length is difficult to mix uniformly and the uneven distribution of matrix does not allow a homogenous distribution of the load to the fibres, which causes lower compressive strength, visible in Fig. 8, photograph d).

6. Having regarded the compressive strength and the mixing, the optimal fibre fraction is between 5 and 30 mm. This fraction will be most suitable for future experiments, enabling the number of tests needed and having good perspective for investigation.

ACKNOWLEDGEMENTS. This project was funded by Tartu College of Tallinn University of Technology.

REFERENCES

Huat, B. B. K., Ali, F. Hj., Maail, S. 2005. The Effect of Natural Fiber on the Shear Strength of Soil. *American Journal of Applied Sciences* (Special Issue), 9-13.

Kouakou, C. H., and Morel, J. C. 2009 Strength and elasto-plastic properties of non-industrial building materials manufactured with clay as a natural binder, *Applied Clay ScienceVolume* 44, Issues 1-2, April 2009, 27-34.

Maddison, M., Mauring, T., Kirsimäe, K., Mander, Ü. 2009. The humidity buffer capacity of clay–sand plaster filled with phytomass from treatment wetlands. *Building and Environment* 44, 1864–1868.

Minke, G. 2006. Building with Earth, Birkhauser, Publishers for Architecture, Basel. 199 p.

Minke, G., Morel, J. C., Mesbah, A., Oggero, M., Walker, P., 2001. Building houses with local material: means to drastically reduce the environmental impact of construction. *Building and Environment*, **36** (10), 1119–1126.

Morel, J. C., P'Kla, A., Walker, P., 2007. Compressive strength testing of compressed earth blocks. *Construction and Building Materials* **2**1 (2), 303–309.

Sargentis, G-V., Kapsalis, V. C., Symeonidis, N. 2009. Earth Building. Models, Technical Aspects, Tests And Environmental Evaluation. *11th International Conference on Environmental Science and Technology Chania*, Crete, Greece, 3–5 September 2009. Available at: http://www.itia.ntua.gr/~fivos/files/Doc/Earth_building.pdf