Unburned Clay Bound Building Materials for Masonry

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The paper presents the experimental research regarding the use in construction field of clay bound earth and wood chips combined with classical binders (cement and lime). New building materials were manufactured (for ground storey houses) by using clay bound and wood chips. The clay bound earth is present all around the Globe. Due to this reason there is one of the most common natural resources of the planet. The wood chips are a waste from wood furniture industry. The paper presents experimental research on mixtures made of clay bound, cement, lime, sawdust and water. Experimental tests were made for: apparent density, bending tensile strengths and compression strengths. The new manufactured building materials have physical and mechanical properties similar to lightweight mortars and bricks. Through clay bound and sawdust reusing a very good impact on environment and life health will be generated. The new building materials studied can be used at non-loadbearing and loadbearing masonry elements. The Batch 4 was the best one, having a bending tensile strength of 3.75 MPa and a compressive strength of 13.41 MPa at 365 days. It has the same mechanical characteristics like bricks made of from burned clay bound. The 25% water percentage is good enough for a satisfactory workability (the material flows to infill the mould); in case of the decrease of the water percentage (especially at 15%), the material has no flow and consequently, is necessary to apply a low pressure (by hand) to infill the mould. A 30% water percentage significantly improves the workability of mixtures.

Keywords: clay bound, wood chips, building materials, wood industrial waste, sustainable materials, environmental protectection, live quality, energy efficiency, eco house, low embedded energy house

The environmental protection and life quality have become important goals for international community. Regarding these problems, the using of natural materials, as clay, could be a sustainable solution. The clay bound is present, from abundance, all around the Globe. It is an environmental friendly material, proper for healthy life. On the other hand, the clay has been used as construction material for thousands of years due to its facile manufacture, low cost and health qualities [1 - 5].Clay bound building materials properties are influenced by water quantity used at manufacture. By using of large quantities of clay bound the final material is humidity sensitive [6-9].In Europe, the clay bound is used as construction material for more than two million buildings. In Romania there are many old, ground storey, houses (especially in the countryside) built 30 years ago which are made from clay bound: masonry and rendering. The building material used is a mix from clay bound, straws/sawdust/wood chips, sand and water. These buildings are still proper to be used and live in [10 - 13].Nowadays, clay bound was *rediscovered* as a building material. All around the world this building material is studied by researchers and more and more is used for buildings [14-18].The present paper regards the experimental research concerning the use in the construction industry of clay bound earth and wood chips combined with classical binders (cement and lime). New building materials were manufactured (for ground storey houses) by using clay bound and wood chips.There are some buildings made only of clay bound masonry or a wooden structure in filled by clay bound masonry.Building materials with clay bound and straws/sawdust/wood chips will have a new interesting future.Some researchers try to use this type of materials to build eco houses or low embedded energy houses or traditional houses [19 - 22].

Experimental part

Materials, compositions and preparation technology

The clay bound mixtures are very sensitive at moisture exposure. Over an optimum percentage of water, the clay bound will have large shrinkage and will present cracks. Due to this aspect, the authors tried to add low percentages of classic binders (cement and lime), sand and wood chips. The lime increased the workability, the cement and wood chips increased mechanical strengths and the sand decreased the plasticity and increased the mechanical strengths.

The present experimental study focused on new building materials made of: clay bound, cement (C), lime (L), wood chips (WD)/polymer fibres (PF), sand (S) and water (W).

In order to settle the mix compositions, the quantity of dry materials were calculated using the next model:

%SDry materials=%S(classic binders+clay+ WD) =100%

where:

- classic mineral binders = cement (C) and lime (L);
- WD = wood chips (wood waste);
- PF = polymer fibres for mortars;
- clay bound = soil extracted from -1.00 m depth.

The characteristics of clay bound soil are presented in table 1 according to the geotechnical study made by S.C. GEO PROIECT S.R.L from Timisoara. The samples from natural soil were showed a brown clay bound.

The cement (C) used was 5 or 10%. It were maintained constant the quantities of: wood chips (WD) 2.5% and sand (S) 10%. The water was 15 or 20 or 25 or 30%.

The cement (C) used was a Romanian product, type CEM I 52.5R produced by CarpatCement Holding, Romania.

The wood chips (WD) were a wood furniture industry waste which had around 8 mm length, presented in figure 1.

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Table 1
GEOTECHNICAL CHARACTERISTICS OF CLAY BOUND SOIL

Geotechnical characteristic	Values
humidity	w = 13.3 – 23.5%
plasticity index	Ip = 34.8 – 48.2 %
consistency index	Ic = 0.94 – 1.09
edometric deformation modulus	M_{2-3} = 9.709 – 20.833 kPa
specific settlement	ε_2 = 0.8 – 3.0 %
interior friction angle	Φ_{uu} = 22.5°
cohesion	c_{uu} = 122.0 kPa
humidity degree	S_r = 0.75 – 0.99
volumic weight	γ = 19.72 – 20.28 kN/m^3
dry volume weight	γ_d = 16.52 – 17.61 kN/m^3
porosity	n = 32.5 – 36.7 %
pores index	e = 0.48 – 0.56

Fig. 1.Wood chips

Batch	Water [%]	Dry material				
		Cement [%]	Lime [%]	Wood chips [%]	Sand [%]	Clay bound [%]
Batch 1 C5 L10 WD2.5 S10	25	5	10	2.5	10	72.5
Batch 2 C5 L10 WD2.5 S10	20	5	10	2.5	10	72.5
Batch 3 C5 L15 WD2.5 S10	20	5	15	2.5	10	67.5
Batch 4 C10 L10 WD2.5 S10	15	10	10	2.5	10	67.5
Batch 5 C5 L10 WD2.5	25	5	10	2.5	-	82.5
Batch 6 C10 L10 WD2.5	20	10	10	2.5	-	77.5
Batch 7 C20 PF0.4 S25	30	20	-	0.4*	25	55
Batch 8 C25 PF0.4 S25	30	25	-	0.4*	25	50

Table 2
MATERIALS COMPOSITIONS

* = Polymer Fibres for mortars

The polymer fibres (PF) are used for mortar manufacture.

It was used the clay bound soil from Gataia town, Timis County, extracted from -1.00 m depth. The sand was a river aggregate with 0/2 granules size.The used lime was CL 90 type (calcic lime).The preparation technology of samples was the following:1.mixing water and cement; 2.adding clay bound and then manually mixing of the intermediate composition for 30 s; 3.adding wood chips and then mechanical mixing of the final composition for 60 s.The compacting was manually done.There were cast 3 batches of 3 prismatic samples of 40x40x160 mm for each. After de-molding, at 1-2 days after casting, the samples were dried by kept in laboratory conditions, at 20°C and relative humidity below 60 %, up to the age of 7.28 and 365 days.During the preparations of mixtures it was noticed that 25% of water was enough for a satisfactory workability (the material flow to infill the mould). When the water percentage was decreased, especially at 15%, the material was not flowing and it was necessary to apply a low pressure (by hand) to infill the mould.

For workability improvement the water content was increased at 30% along with polymer fibres addition for drying shrinkage decrease.

In table 2 are presented the materials' compositions.

Results and discussions

The samples were tested at the age of 7, 28 and 365 days according to the cements' class testing procedure. All the prisms were tested to bending tensile and then the resulted prisms halves were tested to compression.

The results of tests are presented in table 3 and figure 2 for apparent density, in table 3 and figure 3 for bending tensile strength and in table 5 and figure 4 for compressive strength.

At 28 days, the samples had the apparent density values of (1255 – 1530) kg/m^3 which means high density in comparison to burned clay bound bricks for masonry. There are observing that the dried is going until 365 days age.

From table 4 and table 5 it can be noticed:

-at the age of 28 days: the values of bending tensile strength are (0.82 – 3.05) MPa; the values of compressive strength are (3.59 – 11.47) MPa;

-at the age of 365 days: the values of bending tensile strength are (0.91 – 3.75) MPa; the values of compressive strength are (3.02 – 13.41) MPa.

The experimental results show that for Batch 1 and Batch 2 the compressive strength decreased by 15.9% and 15% at the age of 365 days in comparison to the strength at the age of 28 days.

In conclusion, these experimental data demonstrate that:

-the composition of Batch1 and Batch 2 can be used to manufacture non-loadbearing masonry (compressive strength between

2 MPa and 5 MPa);

Table 3
THE APPARENT DENSITY

Batch	Apparent density ρ_a [kg/m^3]		
	7 days	28 days	365 days
Batch 1 C5 L10 WD2.5 S10	1375	1255	1223
Batch 2 C5 L10 WD2.5 S10	1492	1364	1248
Batch 3 C5 L15 WD2.5 S10	1530	1424	1374
Batch 4 C10 L10 WD2.5 S10	1618	1530	1489
Batch 5 C5 L10 WD2.5	1323	1132	1054
Batch 6 C10 L10 WD2.5	1368	1234	1088
Batch 7 C20 PF0.4 S25	1389	1311	-
Batch 8 C25 PF0.4 S25	1453	1328	-

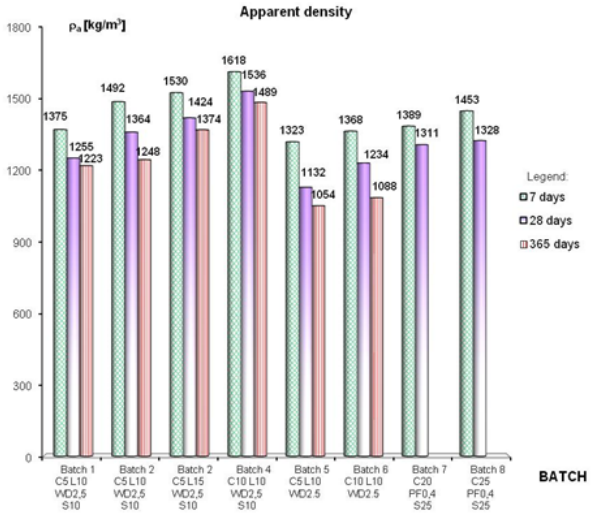

Fig.2. The apparent density

Table 4
THE BENDING TENSILE STRENGTH

Batch	Bending tensile strength f_t [MPa]		
	7 days	28 days	365 days
Batch 1 C5 L10 WD2.5 S10	0.70	0.82	0.91
Batch 2 C5 L10 WD2.5 S10	1.17	1.41	1.64
Batch 3 C5 L15 WD2.5 S10	1.99	2.46	2.58
Batch 4 C10 L10 WD2.5 S10	2.74	3.05	3.75
Batch 5 C5 L10 WD2.5	0.94	1.12	1.29
Batch 6 C10 L10 WD2.5	2.3	2.58	2.81
Batch 7 C20 PF0.4 S25	1.00	1.64	-
Batch 8 C25 PF0.4 S25	1.33	1.89	-

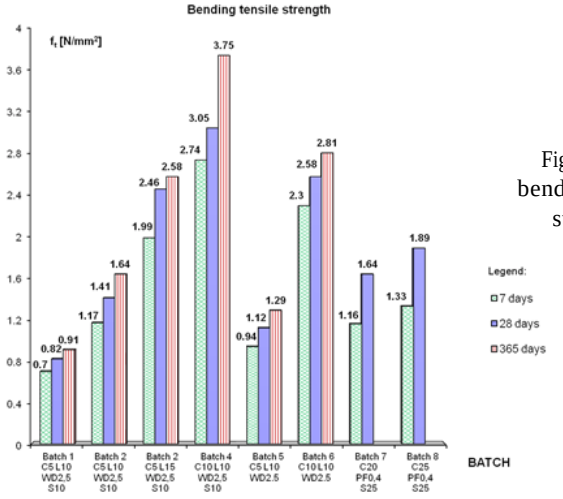

Fig. 3. The bending tensile strength

Table 5
THE COMPRESSIVE STRENGTH

Batch	Compressive strength f_c [MPa]		
	7 days	28 days	365 days
Batch 1 C5 L10 WD2.5 S10	3.32	3.59	3.02
Batch 2 C5 L10 WD2.5 S10	5.18	5.59	4.75
Batch 3 C5 L15 WD2.5 S10	6.77	7.00	7.75
Batch 4 C10 L10 WD2.5 S10	10.09	11.47	13.41
Batch 5 C5 L10 WD2.5	3.36	3.61	2.69
Batch 6 C10 L10 WD2.5	5.99	8.08	8.26
Batch 7 C20 PF0.4 S25	7.86	8.03	-
Batch 8 C25 PF0.4 S25	8.13	8.83	-

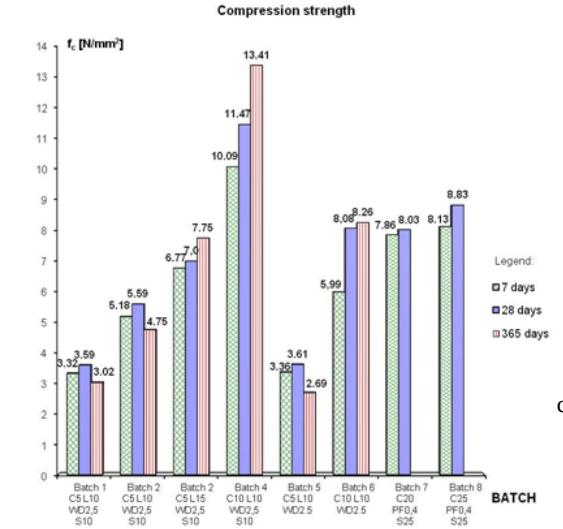

Fig. 4. The compressive strength

-the composition of Batch 3 and Batch 4 can be used to manufacture loadbearing masonry (compressive strength over 5 MPa).

Also, in comparison to Batch 1, the strength of the other batches is significantly improved if the percentage of water decreases and the percentage of cement/lime increases (from 5 to 10%). For bending tensile strength the increase at the age of 7 days is 291% and at the age of 28 days is 272%. For compressive strength the increase at the age of 7 days is 204%, at the age of 28 days is 219% and at the age of 365 days is 344%.

In comparison of Batch 3 and Batch 2, at the age of 28 days, for an increase of 5% lime the compressive strength improves by 25.2%. In comparison of Batch 4 and Batch 2,

at the age of 28 days, for an increase of 5% cement and 5% water decrease the compressive strength improves by 105%. It means that the increase of cement percentage and the decrease of water will generate important benefits in comparison with lime using (there are an ions exchange between clay bound and cement and also chemical hardening reactions of the mineralogical cement compounds).

By comparison of Batch 4 and Batch 3, at the age of 365 days, it can be noticed the increase of cement by 5%, the decrease of water by 5% (at 15%) and finally the compressive strength improves by 73%.

Batch 4 presents very good strengths at the age of 365 days: bending tensile strength of 3.75 MPa and compressive strength of 13.41 MPa, the same as for bricks made with burned clay bound.

Conclusions

The paper presents the experimental research regarding the use in construction field of clay bound earth and wood chips combined with classical binders (cement and lime). New building materials were manufactured (for ground storey houses) by using clay bound and wood chips.

Regarding mechanical strengths it can be noticed that:

-at the age of 28 days: the values of bending tensile strength are (0.82 – 3.05) MPa; the values of compressive strength are (3.59 – 11.47) MPa;

-at the age of 365 days: the values of bending tensile strength are (0.91 – 3.75) MPa; he values of compressive strength are (3.02 – 13.41) MPa.

Results that the compositions of Batch1, Batch 2 and Batch 5 can be used to manufacture non-loadbearing masonry and the compositions of Batch 3, Batch 4 and Batch 6 for loadbearing masonry.

The increase of cement percentage and the decrease of water will generate important benefits in comparison with lime using: the lime increase by 5% improves the compressive strength by 25.2% in comparison to the cement increase by 5% and water decrease by 5% which improves the compressive strength by 105% (at the age of 28 days).

If we compare Batch 1 with Batch 5 at the same water quantities 25% we can observe that by sand using there are not observing a significant different regarding compressive strength.

If we compare Batch 4 with Batch 6 at a decreasing of water quantities with 5% and by sand adding into mixture there are a significant increasing of compressive strength until 42%.

For Batches 2 and 5 were recorded the decreasing of compressive strength from 28 days age at 365 days age due to the mixture dried.

Batch 4 was the best one, having a bending tensile strength of 3.75 MPa and a compressive strength of 13.41 MPa at the age of 365 days. It has the same mechanical characteristics as bricks made with burned clay bound.

The 25% water is proper for a satisfactory workability (the material flow to infill the mould). The decrease of water percentage (especially at 15%) produces no flow of the materials and, consequently, is necessary to apply a low pressure (by hand) to in fill the mould. The increase of water percent at 30% significantly increased the workability.

Building materials with clay bound and wood chips are sustainable materials: clay bound is present in soil; wood chips are an industrial waste; these materials are environmental friendly and proper for human safety. These materials are used to manufacture eco houses, low embedded energy houses, traditional houses.

References

1.BADEA C., SMEU S., GAL A., IURES L., DAN S., Clay Bound Materials Environment Friendly, 12th WSEAS International Conference on Environment, Ecosystems and Development (EED14), Brasov, June 26-28, Romania, 2014

2.OXBURGH R., Clay Materials Used in Construction, Geological Society Engineering Geology, No. 21, Bath, UK, 2002.

3.BRIGATTI M.F., GALAN E., THENG BK.G., Chapter 2 - Structure and Mineralogy of Clay Minerals, Handbook of Clay Science, Elsevier, Developments in Clay Science, Vol. 5, 2013.

4.STOIAN V., DANIEL DAN, TANASA C., SABAU C., STOIAN D., Energy consumption and thermal comfort evaluation for a passive house through monitoring, World Sustainable Energy Days (WSED'14), 26-28 February, Wels, Austria, 2014.

5.PESCARI S., STOIAN V., DANIEL DAN, STOIAN D., Achieving the nearly zero energy building concept - a study based on practical experience, International conference on urban sustainability, cultural sustainability, Green development, Green structures and clean cars, 22-24 November, Firenze, Italy, 2014.

6.PRUSINSKI J.R., BHATTACHARJA S., Effectiveness of Portland Cement and Lime in Stabilizing Clay Soils, Transportation Research Record 1652, Washington D.C., USA, 1999.

7.MCKINLEY J.D., THOMAS H.R., WILLIAMS K.P., REID J.M., Chemical analysis of contaminated soil strengthened by the addition of lime, Eng. Geol. 60(1-4), 2001

8.KINUTHIA J.M., WILD S., Effect of some metal sulfates on the strength and swelling properties of lime-stabilized kaolinite, Int. J. Pavement Eng. 2(2), Elsevier, 2001.

9.BERGAYA F., LAGALY G., Chapter 1 - General Introduction: Clays, Clay Minerals and Clay Science, Handbook of Clay Science, Elsevier, Developments in Clay Science, Vol. 5, 2013.

10.CARMEN MUNTEANU, MARIA GEORGESCU, ANDREEA MONCEA, The influence of fly ash additions associated with policarboxylate superplasticizer on the main properties of Portland cement pastes and mortars, Romanian Journal of Materials, 42(4), p. 350, 2012.

11.RAO S.M., SHIVANANDA P., Role of curing temperature in progress of lime-soil reactions, Geotech. Geolog. Eng., 23(1), Elsevier, 2005.

12.ALEJANDRO D. GONZALES, Energy and carbon embodied in straw and clay wall blocks produced locally in the Andean Patagonia, Energy and Buildings Journal, Elsevier, 70, p. 15-22, 2014.

13.STEVE GOODHEW, RICHARD GRIFFITHS, TOM WOOLLEY, An investigation of the moisture contents in the walls of a straw-bale building, Building and Environment Journal, Elsevier, Volume 39, Issue 12, December 2004.

14.DAN GEORGESCU, RADU PASCU, RADU GAVRILESCU, TIBERIU PASCU, Experimental method for determining the nominal values of concrete shrinkage strains, Romanian Journal of Materials, 45(1), p. 55, 2015.

15.MARIA GHEORGHE, NASTASIA SACA, LIDIA RADU, RACHILA IEREMIE, An experimental model of waste recycling from paper industry as secondary raw material in concrete, Romanian Journal of Materials, 44(1), p. 17, 2014.

16.OTI J.E., KINUTHIA J.M., BAI J., Compressive strength and microstructural analysis of unfired clay masonry bricks, Engineering Geology, 109, Elsevier, 2009b.

17. IURES LIANA, BOB C., The Future Concrete: Self-Compacting Concrete, Iasi, Scientific Bulletin, Tome LIII (LVII), Fasc. 1-2, Constructii,. Arhitectura, Vol. 2, 2010.

18. MIHAI BRATU, OVIDIU DUMITRESCU, OVIDIU VASILE, ALINA CONSTANTIN, MARCELA MUNTEAN, Research on sound-absorbing properties of composite materials with some wastes, Romanian Journal of Materials, 44(2), p. 160, 2014.

19. GRUIN A., ENACHE F., STANCIU G., STANCIU V., Using poured earth to achieve load-bearing elements in buildings, Proceedings of the 7th Edition of Euroinvent, Iasi 14-16 May, 2015.

20.SMEU SILVIA, GAL ANDREI, BADEA CATALIN, Experimental researches regarding insulation materials - Composite materials based on clay and sawdust, MS Theses, Politehnica University Timisoara, 2014.

21.SILVESTRU M., PAUTA R., GRUIN A., TIRTEA A., Rammed Earth Houses as a Sustainable Construction System, 23rd IAPS Conference: Transitions to sustainable societies: Designing research and policies for changing lifestyles and communities, 24 – 27 June, Timi°oara, România, 2014.

22.OTI J.E., KINUTHIA J.M., BAI J., Engineering properties of unfired clay masonry bricks, Engineering Geology, 107, Elsevier, 2009

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