

## **Ecological, clay-based building engineering**

PIOTR MAŃKOWSKI, SŁAWOMIR KRZOSEK, MICHAŁ MIKOŁAJKO

Katedra Nauki o Drewnie i Ochrony Drewna SGGW w Warszawie

*Abstract: Ecological, Clay-based building engineering, Latest years come with increased pressure of ecological trends in building. Newest trend in building industry is use of clay, many buildings made of clay with addition of straw and wood chips.*

Strength testing was done on the Instron 3282 machine. After addition of filling, compression strength reduces. Addition of straw in clay significantly increases deformability of loaded adobe bricks.

In article presents dependence between force and deflection of tested samples

*Keywords:* wooden architecture, adobe clay brick, wood.

### INTRODUCTION

Latest years come with increased pressure of ecological trends and movements on our lives. Such activities improve human's life quality and reduce his negative impact on environment and nature. Ecological food and renewable energy steadily gain new enthusiasts. Also, increased number of electric vehicles on our streets is noticeable.

Ecological, renewable fuels (canola oil, bioethanol) and energy sources (solar cells, wind turbines) became more important alternatives to traditional coal.

Ecological thinking found its place also in housing. Ecological building materials are being produced, share of ecological wooden housing is also constantly increasing. Newest trend in building industry is use of clay, obviously not being any new idea, but refreshed technique of the past (Czajkowski 2011).

Clay buildings are one of the most traditional dwellings, they were built in ancient past, numerous traces of them are being found in archeological excavations (Broniewski 1990).

Buildings made of clay were present in places with wood deficiency. Development of adobe buildings is strictly connected with poverty, last time of popularity of such technique was during postwar years, with devastated forests and lack of wood for traditional (Fryczowa 1961).

Oldest known adobe made city is Jericho, material like green brick was known also in ancient Egypt. Mesopotamia, usually utilized adobe as well, but more presentable buildings, such as palaces, were set with burnt brick. Cottages were built with reed bonded with [Broniewski 1990].

Historical sources mention about buildings made of sun-dried green brick, and ones with walls made of clay packed between the wooden or wicker „formwork”. Clay may be used for manufacturing of both burnt and green bricks.

Most common applications of adobe are:

- a) laying walls of brick with various additives, improving insulation and mechanical properties of the material,

- b) building of walls by preparation of formwork and filling with wedged clay, interleaved with straw, blueberry bush, juniper branches and conifer needles. Highest building made with such material is five story housing in Weilburg,
- c) walls in half-timbered framework, where structure is built of wood and then filled with clay with various additives, like Kościół Pokoju in Jaworze.

Wide application of adobe brickwork in Poland is testified (except literature and numerous pictures of buildings) by existence of industry standards describing manufacturing and testing of adobe brick [BN-62/6738-02]. As a additives for adobe brick straw, chaff, moor, sawdust, juniper and fine wood fraction are being used (Piaścik 1953, Szewczyk 2011).

Burned brick appeared later. After burning, brick improves its mechanical properties and service life, however, this procedure requires significant amount of energy.

In Poland, ecological building industry develops, many buildings made of clay with addition of straw are designed and built [www.jg-architekt.manifo.com/].

Return to traditional adobe-straw brick is being observed, however, such return to traditional materials utilizes modern tools and technology (fig 2.).

Glaring example of such clay building is Pavilion 512 In Warsaw’s Copernicus Science Center (fig. 1.).



**Fig. 1.** Wall of Pavilion 512 of Copernicus Science Center in Warsaw, made of clay  
[www.512.kopernik.org.pl/pawilon-512.html]



**Fig. 2.** Contemporary building made with wood, clay and straw.  
[www.jg-architekt.manifo.com/]



**Fig. 3.** Green clay-straw bricks  
[www.chemiabudowlana.info]



**Fig. 4.** Example of wall made of wood and clay

Interest of building contractors on traditional technologies caused clay, appearing as research topic. Dependence between strength and density of adobe brick is described by Kouakou [Kouakou, Morel, 2009], force-deflection characteristics for various fillers is presented by Galán-Marín [Galán-Marín et al 2010].

The same force-deflection characteristics for straw filled bricks is described by Rogiros [Illampas et al. 2014].

Moisture content and compression strength characteristics were researched by Oti [Oti et al, 2009]. It was determined that compression strength is proportional to the length of drying period (moisture content drop)

Following work describes mechanical parameters of adobe brick with natural fillers.

## MATERIALS

Clay was acquired from Piaseczno region (clay bed was at 120 cm depth).

As a filler following materials were used:

1. rye straw, conditioned for two years, before mixing with clay straw was cut into 3-5 cm pieces
2. pine wood chips (from planer)

3 types of bricks were prepared: Pure clay (G), clay with 5% straw addition (GS5) and clay with 5% chip addition (GW5). Bricks were of 10x10x10 [cm<sup>3</sup>] dimensions.

30 test bricks of each type were formed. Forming was done manually, ready bricks were dried down to constant mass. Straight bricks without visible cracks, were selected for testing, density and compression strength was determined. Strength testing was done on the Instron 3282 machine.

## RESULTS

Table 1 presents density measurement results of clay and clay-filler bricks. Average density of pure clay bricks reached 1,96 g/cm<sup>3</sup>. Filler addition resulted in drop of density, drop was larger for bricks with straw.

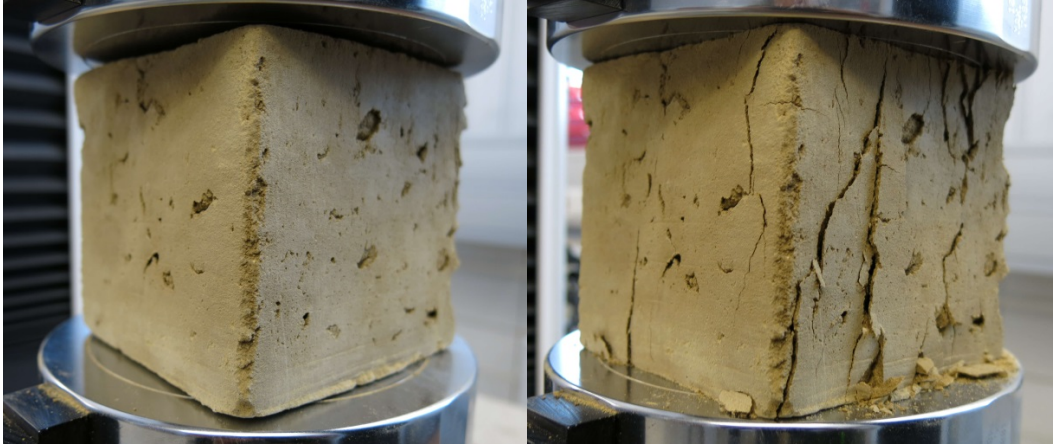
**Tab. 1.** Average density of tested bricks.

Density		G	GS5	GT5
Average	[g/cm <sup>3</sup> ]	1,96	1,37	1,62
Max	[g/cm <sup>3</sup> ]	2,01	1,46	1,72
Min	[g/cm <sup>3</sup> ]	1,91	1,25	1,53
Standard deviation	[g/cm <sup>3</sup> ]	0,03	0,05	0,05
Numer of samples	[-]	21	23	22

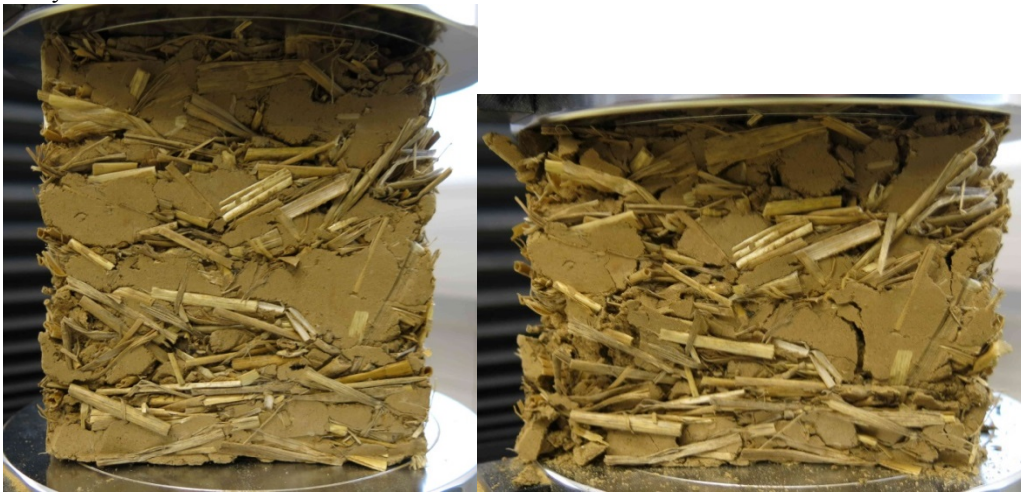
Bricks were tested against compression strength in Instron testing machine, force and deflection were measured. Figure 5 presents pure clay brick (G) before and after testing. Again, figure 6. shows straw-filled brick (GS5) and figure 7 chip-filled one (GT5).

For bricks of G group measured deformation was negligible, every tested sample showed fracture in the form of vertical cracks. Highest distortion was reached for GS5 group (fig. 6., fig. 8.)





**Fig. 5.** Pure clay bricks in natural state and after destruction.



**Fig. 6.** Straw-clay bricks in natural state and after destruction



**Fig. 7.** Chip-clay bricks in natural state and after destruction

**Tab.2.** Strength of tested bricks

Strength		G	GS5	GT5
Average	[MPa]	3,3	2,6	2,8
Max	[MPa]	4,3	3,7	3,5
Min	[MPa]	2,3	1,2	2,4
Standard deviation	[MPa]	0,5	0,6	0,3

Average compression strength of pure clay bricks (G) reaches 3 MPa. After addition of filling, compression strength reduces. Addition of 5% (weight) straw, has more significant negative impact on strength than addition of 5% chips. In case of straw-filled bricks (GS5) average compression strength equals 2,6 MPa. With chip addition (GT5) average compression strength is higher and reaches 2,8 MPa.

Compression strength of tested bricks is comparable with bricks with addition of sand and straw/chips described by Woroszyńska-Burzak [[www.biobudownictwo.org](http://www.biobudownictwo.org)]

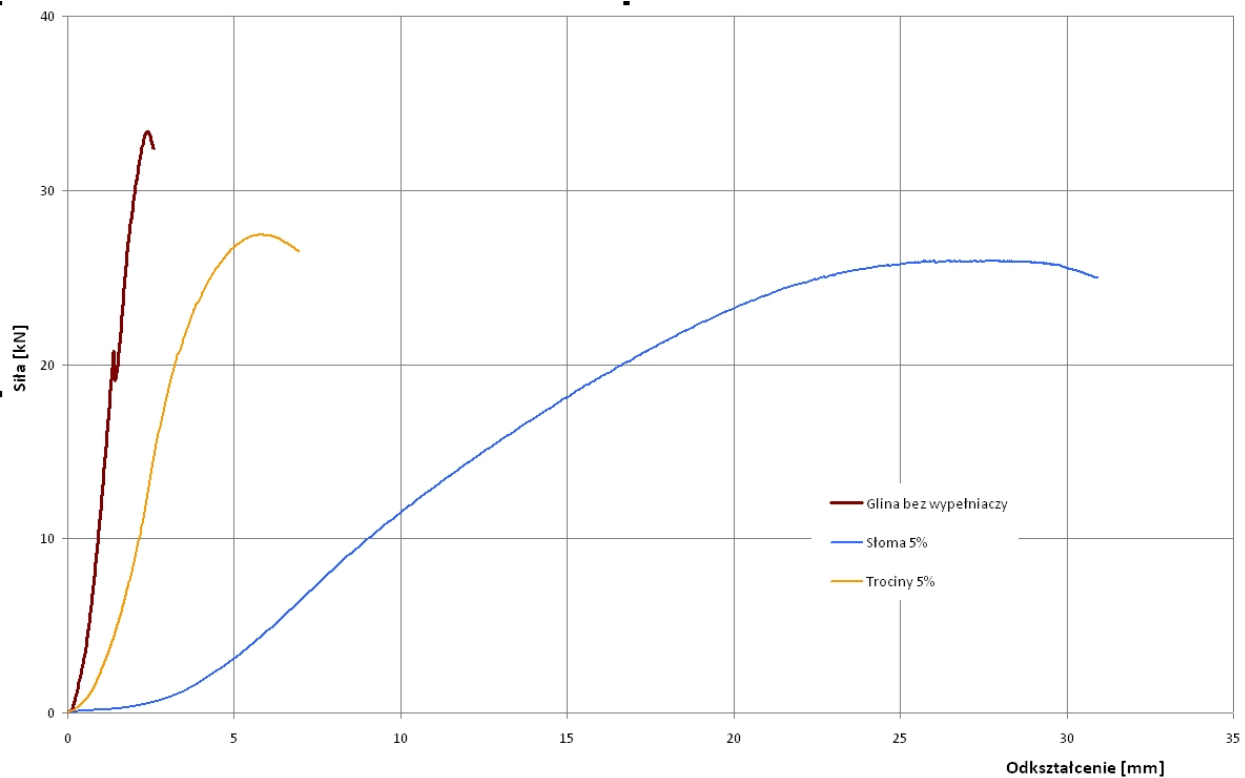
**Fig. 8.** Force-deflection characteristics

Figure 8 presents dependence between force and deflection of tested samples. In bricks of G group (pure clay) increased force causes only marginal deflection, in GT5 (clay-chips) deflection is higher, but comparable to G group. GS5 (clay-straw) group shows higher distortion. In samples of this group, significant deformation of straw layers occurs – distortion of these bricks is 5 times higher than in comparable chip-filled bricks with similar forces applied.

## CONCLUSION

Increased interest in ecological building is being observed.

Clay is one of the materials used in ecological building.

Clay with natural filling (straw, wood chips) is appropriate for production of green bricks.

Addition of chips in clay insignificantly diminishes density and strength of adobe bricks.

Addition of straw in clay significantly increases deformability of loaded adobe bricks.

## REFERENCES

1. BRONIEWSKI T. 1990: Historia architektury, Ossolineum Warszawa
2. CZAJKOWSKI J. 2011: Dom drewniany w Polsce, tysiąc lat historii, NOMOS Kraków
3. GALÁN-MARÍN C., RIVERA-GÓMEZ C., PETRIC J., 2010: Clay-based composite stabilized with natural polymer and fibre, *Construction and Building Materials* 24 (2010) 1462–1468
4. FRYCZOWA M. 1961: Tradycyjne budownictwo ludowe Kujaw, Muzeum Etnograficzne w Toruniu
5. KOUAKOU C.H., MOREL J.C., 2009: Strength and elasto-plastic properties of non-industrial building materials manufactured with clay as a natural binder, *Applied Clay Science* 44 (2009) p. 27-34
6. OTI J.E., KINUTHIA J.M, BAI J., 2009: Compressive strength and microstructural analysis of unfired clay masonry bricks, *Engineering Geology* Vol. 109, Issues 3–4, 20 November 2009, p. 230–240 (cegły z dodatkiem wapna i cementu: skurcz, wytrzymałość, mikroskop)
7. PIAŚCIK Franciszek, 1953: Budownictwo wiejskie z materiałów miejscowych, PWRiL Warszawa
8. ROGIROS ILLAMPAS, IOANNIS IOANNOU, DIMOS C. CHARMPIIS, 2014: Adobe bricks under compression: Experimental investigation and derivation of stress–strain equation, *Construction and Building Materials* Vol. 53, 28 February 2014, pp. 83–90
9. SZEWCZYK Jarosław 2011: Nietypowe materiały budowlane – glina, gnój i domieszki – w świetle dawnego polskiego piśmiennictwa cz. 1. klepiska, podłogi, ściany i tynki
10. *Architecturae et Artibus* - 4/2011 p.21-51
11. BN-62/6738-02 - Budownictwo z gliny. Masy gliniane
12. [www.512.kopernik.org.pl/pawilon-512.html](http://www.512.kopernik.org.pl/pawilon-512.html)
13. [www.jg-architekt.manifo.com/](http://www.jg-architekt.manifo.com/)
14. [www.chemiabudowlana.info/](http://www.chemiabudowlana.info/)
15. <http://biobudownictwo.org/wspolpraca-z-politechnika-lub/badania/>

**Streszczenie:** *Ekologiczne budownictwo z gliny.* W ostatnich latach obserwuje się wzrost zainteresowania budownictwem ekologicznym. Jednym z materiałów stosowanym w budownictwie ekologicznym jest glina. Glina niewypalana z wypełniaczem (słoma, trociny) jest dobrym surowcem do wytwarzania cegieł.

Wykonane w warunkach laboratoryjnych cegły poddano ścisłaniu w maszynie wytrzymałościowej Instron, podczas testu mierzono przyłożoną siłę i spowodowane nią odkształcenie. Po dodaniu wypełniacza wytrzymałość na ścisłanie maleje. Dodatek słomy powoduje większy spadek wytrzymałości na ścisłanie niż dodatek trocin. W pracy przedstawiono zależność pomiędzy przyłożoną siłą a odkształceniem cegieł.

#### Coresponding authors:

Piotr Mańkowski  
Warsaw University of Life Science, Faculty of Wood Technology  
Department of Wood Science and Wood Protection  
Warsaw Poland  
Nowoursynowska 159 02-787 Warszawa  
e\_mail: piotr\_mankowski@sggw.pl  
(48-22)-59 38 638

Sławomir KRZOSEK  
Warsaw University of Life Science, Faculty of Wood Technology  
Department of Wood Science and Wood Protection  
Warsaw Poland  
Nowoursynowska 159 02-787 Warszawa  
e\_mail: slawomir\_krzosek@sggw.pl  
(48-22)-59 38 633

Michał MIKOŁAJKO  
Warsaw University of Life Sciences, Faculty of Wood Technology