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INVESTIGATIONS ON THE CONSTRUCTION MATERIALS FROM ROMANIAN MIDDLE AGE MONUMENTS

E. DAN[1] N. NOICA[2] M. MUNTEAN[3]

Abstract: *The paper brings information regarding compositionally characteristics of the mortars used at the Targoviste princely court buildings, in three different historical periods, during 200 years, between 1350 – 1584 years. The researches have point out an evolution in time of a used construction techniques, meaning aggregates granularity, accordingly with the mortar porosity reduction. On the other side, the obtained results, on the samples considered by the authors being from the same period had similarly results.*

Key words: *middle age, masonry, Targoviste, princely court, normative.*

1. Introduction

Long time resistance of some built in stone and brick constructions from our ancestors provokes, even today, expert's admiration, end in the same time, the curiosity to know the materials and technique used to achieve them.

In a reference paper [1], published in 1927 year, the architect – eng. Nicolae Ghica – Budeşti used the following words, to describe the construction's materials and proceedings used at the romanian midle age buildings, realised between XIV – XV centuries:

„Boulders and careve stones make, together with the bricks, the construction material. Construction procedures are the Byzantine ones: horizontal stone rows, drowned in a lime mortar, mixed with small gravel alternate with many rows from apparent bricks. This brick assizes stabilised, at the quite near levels, perfect horizontal plans, wich can stabilized the stone masonry; boulders, having unregulry forms, the masonry is exposed at unequal subsiding, able to bring cracks.

Fig.1 – *Targoviste – whales of princely court buildings*

[1] Transilvania University of Brasov.
[2] Prefab Invest SRL Bucharest.
[3] Politechnica University from Bucharest.

There is well known that the white lime mortar – the only one known in those times, have a slow prize, and the rapid raisingage of the masonery is able to provoque dislocations, before the mortar prize.

Probably for the same reasons, the masonry was made using wood shuttering, in order to sideways sustaine the bricks with the mortar. It's also possible that masonry was erected using „hot lime" mortar. All these assumptions show that are lost the building process with the white lime secrets".

The resistance in time of the Targoviste princely court walls awake our curiosity about used construction materials characteristics, using present means and techniques.

Fig. 2 – *Chindia Tower*

2. Material and methods

The approximate age of the researched objectives, indicated by the architects is given in the table no. 1.

Mortar samples from the Targoviste princely court buildings Table 1

Historical period	**Origin place of the samples**	**Sample's no.**
1350 – 1395	- „ pârcălabului" house foundacion - western wahll of the Mircea the Old hospodar house	1 2, 3
1395 – 1400	- cellar of Mircea the Old hospodar house - chapel wahll elevation ;	4 5
1584	- Petru Cercel period buildings	6, 7

The sampling was made by the core drilling, considered an optimum method, wich allow the representative samples obtaining. There war made phisicaly, chemicaly and mineralogicaly tests using actually investigation methods.

The mortar samples, taken as holesaw from the "situ" was prepared for analises, first, by disaggregation, for component separation. For this purpose we used thermal decomposition method, used for the first time by prof. dr. Serban Solacolu [2]. The method consists of a series of cycles of sample mortar (or concrete) strengthened heating to a temperature close decarbonation temperature (800-850 0C), followed by a sudden cooling in air.

The chemical composition of the mortar binder was estimated using the professor Al. Steopoe method, based on the mortar chemical composition, of which was excluded insoluble in HCl, believed as belonging to aggregate (sand).

3. Results and discussion

Samples from masonry construction elements were analized and the results revealed the used construction system consisting of alternate rows of brick and rough stone, bonded with lime mortar.

Optical microscopy analyzes performed on thin sections, made of bricks and mortar, showed good adhesion of the mortar in masonry elements. Not found to alter the surface area of contact between elements of masonry and mortar.

3.1. Mortar

In terms of quality mortars, it was evaluated by porosity, density (Table 2) and report binder: aggregate on thermal disaggregated samples (Table 3).

Physical characteristics of mortars Table 2

Characteristic	**Sample no.**				
	1	2	3	4	6, 7
Bulk density, g/cm^3	1,52	1,64	1,62	1,61	1,80
Porosity,%	37	32	32	33	27

Composition mortar. Binder / aggregate report Table 3

Historical period	**1350**		**1400**		**1584**
Proba nr.	1	2	3	4	6, 7
binder, %	40÷45	25÷30	25÷30	30÷35	40÷45
aggregate, %	55÷60	70÷75	70÷75	65÷70	55÷60
inder/aggregase	1/1,4	1/3	1/3	1 / 2,2	1/1.4

Aggregates / binder rate was variable, between 1/1, 4 ÷ 1/3.

3.2. Binder

Binder chemical characteristics, from the analyzed mortar samples (Table 4) show that, in all cases were used lime as binder, from lime pepper to hydraulic lime, depending on purity limestone rock used in its manufacture.

Mineralogical analysis, by optical microscopy on thin sections, confirm the nature of the binder, the presence of microcrystalline calcite (25 ÷ 45%), resulting from the carbonation of the lime binder.

Chemical characteristics of the mortar binder samples Table 4

Historical period	**Sample no.**	P.C.	**Oxides, %**					**The basicity modul ***
			SiO_2	**Fe_2O_3**	**Al_2O_3**	**CaO**	**MgO**	
1350	1	39,28	8,23	1,88	3,04	46,28	1,17	3,61
	2	32,13	17,56	4,99	6,80	33,51	2,64	1,23
1400	3	33,80	11,04	4,88	7,41	39,79	1,74	1,78
	4	36,41	13,29	2,36	3,07	41,94	0,91	2,29
	5	42,95	4,53	1,50	2,23	47,59	1,19	5,90
1584	6, 7	46,38	n.d.	1,40	1,44	49,89	0,88	n.d.

*The basicity modul: M_b= (%CaO+%MgO) / (%SiO_2+%Al_2O_3+%Fe_2O_3), value proportional to the purity of lime (CaO content size).

3.3. Aggregate

Aggregate characterization was performed by determination of mineralogical composition and granulosity.

Table 5 shows the aggregates mineralogical composition of the investigated mortars.

Aggregate grain shape, observed in optical microscope has rounded corners due to the run, indicating a probable origin of fluvial sedimentary accumulations.

Aggregate granules form, of the investigated samples, from different historical periods shows that they come from the same source, probably thr local one.

Mineralogical characteristics of mortars investigated aggregates Table 5

Sample no.	Radiography X-ray diffractometer				Comments
	Quartz	Calcite	Feldspar	Mice	
1	50	40÷45	5	1	-
2	65÷70	20÷25	5÷10	3÷4	Quartz mineral is predominantly observed by optical microscopy
3	65÷70	25	5÷10	2÷3	Calcite is mainly used as a binder in lime mortar
4	60÷65	30÷35	5	2	
5	50	40	5	1	
6, 7	55	40÷45	5	1	Felspații and small are secondary minerals in the sand

The most interesting results are those concerning the granularity unit, represented diagram from Figure 3. As shown in Figure 3, the grain size ranges, mainly between 0.08 ÷ 2.0 mm, corresponding to fine sand to the sea, with predominance of small classes (possibly due to thermal decomposition method).

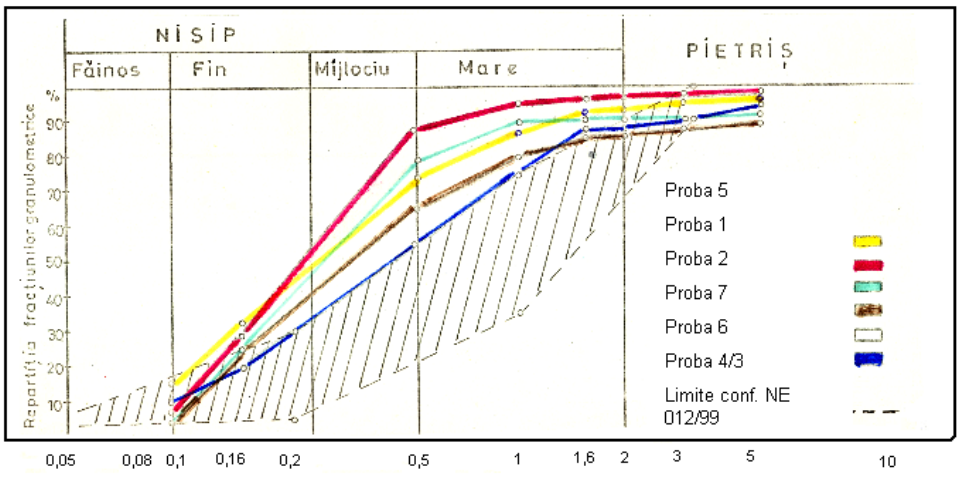

Fig. 3. *Grading curve of the aggregate in mortar samples investigated*

Analyzing the curves of grain aggregates compared to the norm for concrete deadline set by U.S. 012/99 (range hatched) shows the following:

- diagrams corresponding samples 1 ÷ 4 is located in an area above the normal range, with a higher proportion of fine fractions;
- Diagram of aggregate granularity of samples 6 and 7 overlaps the upper limit of the shaded area, indicating a composition in accordance with current size sand, shorts 0 ÷ 3 mm.

Given the above, it can be said that mortars belonging to the most recent historical period - 1584, Petru age composition Earring are optimized in the sense of granularity unit. This feature is reflected in the quality of the mortar, the lower porosity (27% versus 32 ÷ 37%) and higher density (1.8 versus 1.5 ÷ 1.64), which corresponds to better sustainability.

Fig.4 – *Buildings from Petru Cercel historical period*

Fig.5 – *Stone and brick walls in Târgovişte princely court (Ghizmo)*

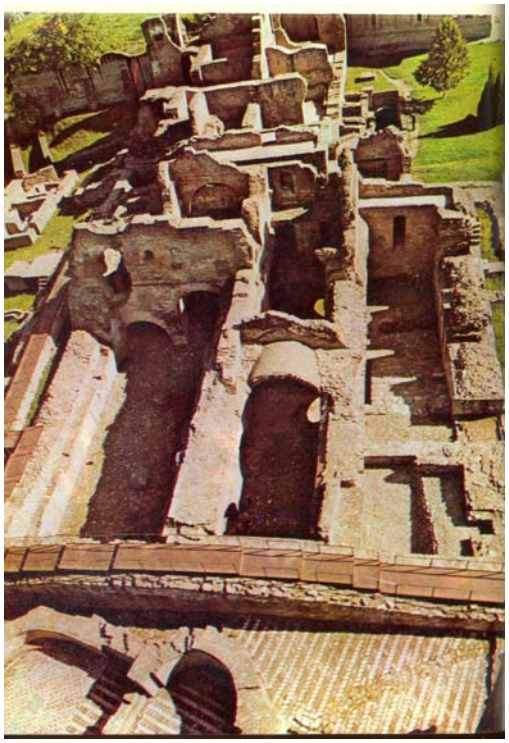

Fig.6 – *Walls from Mircea The Old, period (Ghizmo)*

Fig.7 – *Târgovişte Walls (Ghizmo)*

Fig.8 – *Târgovişte princely court buildings Walls (Ghizmo)*

4. Valorization of research results

Presented research work has served as a database for development "**Methodology for investigating old masonry" - indicative MP 007-99**, prepared by PROCEMA SA, approved by Order MLPAT no. Construction 48/N/2.08.1999 published in Bulletin vol. 8/2000.

This methodology is a first attempt of synthesis of existing information on editing, provided by skilled specialized institutes and institutions, for expertise in construction and provides to technical experts in construction one correct way of action to diagnose the state of a technical ceramic masonry.

Further research is needed in order to extend the database, to allow correct interpretation of the NDT measurements on ceramic masonry structures of historical periods as large.

5. Conclusions

There are investigated samples from building materials belonging of three successive historical periods, along the approx. 200 years:
- The period before 1350 (Parcalab house - foundation);
- during 1395 - 1400, (walls of royal house of Mircea the Elder):
- during 1584 - (walls of royal house of Petru Cercel), are investigate

In the three investigated periods were used the same materials in construction of buildings inside the Princely Court in Targoviste. Was found a positive development of used construction techniques, consisting in a mortar density improvement, in the recent years investigated, due to granularity optimization unit. The obtained results also showed that the samples dated by archaeologists as belonging to the same historical period have similar characteristics.

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