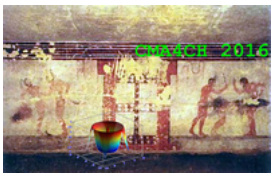
CMA4CH 2016, Mediterraneum Meeting
Straightforward approach in Cultural Heritage and Environment studies - Multivariate Analysis and Chemometry
6th ed., Rome, Italy, Europe, 18-20 December 2016



Cluster Analysis to Discover Similarity Among Bricks for Restoration and Original Roman Age Bricks

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Abstract

This study, started from a request of a restoration équipe during works on the roman building "Minerva Medica" (Rome), treats of survey on the conservation bricks used in the integrations. We obtained some samples of the original roman bricks and of those used for the integration. We looked for the better chromatic relationship between the two series of bricks in order to confirm the respect of the Cesare Brandi's restoration theory in the work of integration on the buildings. A spectrophotocolorimeter was used for the analyses and data, here presented in coordinates CIELab, have been treated by the cluster analysis.

Introduction

Minerva Medica is a Roman building dating back to the fourth century BC, located in via Giolitti, that in this year has been object of a conservative restoration work, carried out on the behalf of the Soprintendenza Speciale per i Ben iArcheologici di Roma, to reconstruct missing parts of the monument [1]. Basing on the Cesare Brandi's restoration theory, the integration of such parts is allowed but must be done with visually similar but recognizable materials [2].

On these bases, the colour is an essential requisite for the integration bricks; so, the CIELab coordinates of some integration bricks were compared with those of original roman ones.

The importance of a detailed study on roman bricks is given by their recurring presence in significant architectural structures that are now lacking in plaster and exposed to degradation. Romans called these materials lateres or tegulae; the more confirmed theory about the production of roman bricks considers the creation of a squared shape with two diagonals engraved on the surface that permits, after the brick firing, to obtain four triangles through an hammer's knock, in order to have a corner to insert in the lime and a plane surface exposed.

The clay, brick's essential constituent, is an incoherent sedimentary fine-grain rock that is principally constituted by hydrous aluminium silicates ($xAl_2O_3 \cdot ySiO_2 \cdot zH_2O$) but other not clay minerals are also naturally present or artificially added in order to modify physical characteristics of the material (as the colour).

Materials & Methods

Five integration bricks (CBA1, CBB1, CBC1, CBD1, CBD2) and 3, unknown aged, roman bricks (RBA1, RBB1, RBC1).comes from Minerva Medica while 2 others integration bricks (CBE1, CBE2) comes from the Carcere Mamertino (Foro Romano).

Chromatic measures were performed, by a digital portable spectrophotocolorimeter Konica Minolta 2600d equipped with SpectraMagic software for data processing, in the following experimental conditions: CIELab colour space; illuminant D65; observer: 10°; 8 mm mask diameter (MAV); UV component excluded (SCE), average value of three consecutives measures at 0.5 sec distant.

36 points, three for each face, have been analyzed on each brick in wet (using distilled water) and dry conditions. From the L*a*b* coordinates of the three points on each face, the average, the standard deviation, the median and the difference between quartiles $q_{3/4}$, $q_{1/4}$ have been calculated. The cluster analysis has been made with the MVSP (Multi-Variate Statistical Package) software version 3.22 (Kovach Computing Services), with the following settings: nearest neighbour as clustering method, Euclidean distance, no data transformation.

Results

A comparison between each face average, associated to standard deviation, and each face median, associated to difference between $q_{3/4}$ e $q_{1/4}$, revealed a no significant differences; so the median, the value in the middle of a distribution, has been chosen to represent, in the cluster analysis, the distribution of the L*a*b* coordinates.

The tables and the respective dendrograms summarize the results obtained from the cluster analysis for dry samples (Tab. 1 and Fig. 1) and for the wet ones (Tab. 2 and Fig. 2). The original roman bricks and integration bricks are reported in red and blue respectively.

As it regards the bricks in dry condition (Tab 1 and fig 1), a chromatic similarity between the CBB1, CBE1 and the roman RBA1 is evidenced while the colour of CBC1 and CBA1 resulted more similar to the one of RBC1. Even if CBE1 and CBE2 came from the same site, they are not in the same group, maybe because of the non homogeneity in colour of the single bricks. CBD1 and CBD2 have the same problem that in this case must be imputed to the second brick that presents a rosy compact ring that lightens surface. No one of the integration bricks seems to be suitable for integration of bricks like the one RBB1 (crimson red).

Tab. 1; Euclidean distances between all dry samples in growing order, from the nearest to the farthest.

Node	Group 1	Group 2	Dissimilarity	Objects in group
1	CBB1	CBE1	10.592	2
2	Node 1	RBA1	12.952	3
3	Node 2	CBE2	13.560	4
4	CBA1	CBC1	14.135	2
5	Node 4	RBC1	15.197	3
6	Node 5	CBD2	19.282	4
7	Node 6	Node 3	20.280	8
8	Node 7	CBD1	20.540	9
9	Node 8	RBB1	23.165	10

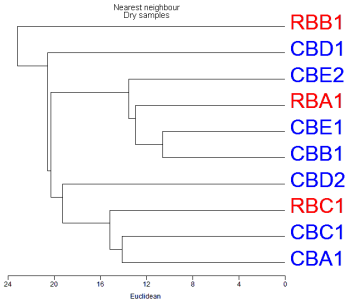

Fig. 1; Dendrogram of dry samples.

Passing to wet condition, a decrease of L* and an increase of a* and b* occur for all the bricks. CBE1 and CBE2 lose the dissimilarity seen on dry surfaces. The distance between CBD1 and CBD2 increases because of the rosy ring that, being impermeable, doesn't change colour under the effect of water. In this condition CBC1 results perfect to integrate the roman RBC1. Finally, also in wet conditions there are no conservation brick suitable to integrate RBB1 (Tab 2 and fig 2).

Tab. 2; Euclidean distances between all wet samples in growing order, from the nearest to the farthest.

Node	Group 1	Group 2	Dissimilarity	Objects in group
1	CBE1	CBE2	10.093	2
2	CBB1	Node 1	10.935	3
3	CBA1	CBD2	11.950	2
4	CBC1	RBC1	15.833	2
5	Node 3	Node 4	16.132	4
6	Node 5	RBA1	16.243	5
7	Node 6	CBD1	17.019	6
8	Node 7	Node 2	18.086	9
9	Node 8	RBB1	23.342	10

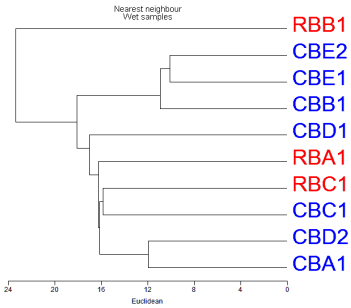

Fig. 2; Dendrogram of wet samples.

Conclusions

This study has enabled the first use of the cluster analysis to make a selection, based on colour, of the integration brick more suitable to restore stability to the original roman masonries in bricks during a restoration work. It has been fundamental a testing of the colour both on wet and dry surface because, after laying, in our case of outdoor artifact, the brick is exposed to rain and to capillary rise of water that involves a chromatic change; in the last case, an inlet of soluble salts occurs which leads to the same effect, as we seen for the sample CBD2.

References

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2) Cesare Brandi, *Il restauro – Teoria e pratica*, Editori riuniti, 2009, ISBN 978-88-359-8009-4