

EROSION EVALUATION OF THE BAS RELIEVES OF S.MICHELE BASILICA IN PAVIA

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ABSTRACT

S. Michele Basilica is the most ancient Romanesque church (XII Century) in Pavia and one of the best of that period in all the North of Italy. Here kings and emperors were crowned during the Middle Ages. The facade of the Basilica, built in sandstone is rich in bas relieves.

Due to many causes, such as atmospheric pollution and others which are not well known, the facade has been seriously damaged during the last forty years.

The most impressive damage due to atmospheric pollution is the bas relieves continuous erosion.

In '70s a large part of the facade has been surveyed by the usual close range photogrammetric techniques. In 1999 all the facade has been surveyed.

This paper presents the results of the first comparison between the new close range photogrammetry survey and the previous one, of '70s.

1 RESEARCH AIM

S. Michele Basilica is the most notable monument of Romanesque Lombard architecture. Paolo Diacono reports about the existence of a S. Michele devoted basilica in 642. Here Longobard and kings of the Italic Kingdom were crowned; even Frederick Barbarossa was crowned emperor in 1155.

The actual building was built between 1090 and 1100 on the ruins of pre-existing buildings.

The most suggestive element of S. Michele Basilica is represented by the façade made in blonde sandstone engraved and adorned with splendid bas relieves, representing fantastic decorative motifs like dragons, sirens, archers, griffins, but also scenes inspired by biblical episodes and everyday life moments.

Unfortunately S. Michele stone is a very brittle sandstone; it suffered important deterioration over the centuries. From 1860 to 1875 restoration works and, when necessary, replacements of antiques figures with copies in sandstone extracted ex novo from a quarry were made.

However it is from the second post war period that S. Michele sandstone started to have a tragic degradation.

In '60s a complex preservation operation has been realised on the all facade. It consisted of a chemical treatment with zinc and magnesium fluorine silicate.

Unfortunately just ten years after the application of this chemical treatment, the sandstone degradation phenomenon started again in a dramatic way.

Probably the interaction between the chemical agent and the stone determined the creation of a chemical dishomogeneity on the bas relieves superficial layers.

At this point, only the photographic images remain to document the past magnificence, since a metric survey of the whole facade wasn't realised in the past.

So it is not possible to evaluate in a quantitative way the damage by which the façade was affected, as its several representations have been realised with the usual pictorial style which doesn't allow precise metric measurements of the morphologic shapes of architectural and ornamental particulars.

The aim of this research is to test a method, mainly based on the usual photogrammetric techniques for achieving a precise quantitative evaluation of the damages by which the façade was affected.

This task being obtained in term of erosion measured on historical series of data.

2 THE SURVEYS

2.1 The past surveys

The only complete surveys of S. Michele facade were realised with direct traditional survey techniques.

The very beautiful engravings made in 1865 by De Dartein are an example of direct survey.

A more recent survey was realised in '60s by Sampaolesi.

From engravings and direct surveys we can obtain qualitative data, but no metric datum about bas relieves thickness.

Unfortunately a complete photogrammetric survey of the facade was never realised.

In 1940 Cassinis surveyed, with photogrammetric methods, a facade sample. This sample was surveyed later in '80s (Bezoari 1987 e 1996).

In '70s an important part of the facade was surveyed with photogrammetric methods; the survey was performed by unique stereoscopic model.

The graphic elaborates, made in indeformable material, were available to the authors.

2.2 '99 surveys

In May 1999, in the only week, after fifteen years, when the facade was completely free of scaffoldings, a photogrammetric survey campaign was made in order to:

- achieve a complete photogrammetric cover of S. Michele's facade, as current state documentation,
- realise the rigorous photogrammetric analytical restitution, prioritising the sample surveyed in '70s and now digitised,
- effect comparison elaboration between new surveyed data and digitised data.

The photogrammetric survey was planned in order to produce final numeric data with following precision: ± 2 mm for the all facade, ± 1 mm for the sample surveyed in '70s and now digitised.

In order to obtain this precision we made two different series of shots at different distances off the façade.

The whole facade was taken at 10 m of distance to obtain photograms on a scale 1: 250; the sample surveyed in '70s was taken at 4 m of distance to obtain photograms on scale of 1:100.

The camera used is a Rolleiflex 6008, lens 40 mm.

The whole facade was taken with 3 stripes of 7 photograms each, made at 5.75 m, 13.75 m, 21.75 m of elevation.

Topographic control survey ('99 datum) was realised, in order to achieve exterior orientation data of the stereomodels. The measurements was made by a Leica T460D and a Leica DISTO instruments.



3 AVIALABLE DATA FOR EROSION EVALUATION

In order to evaluate erosion phenomena in metrical terms and not only qualitatively, two data set have been used. The first to be derived from '70s photogrammetric survey, and the second by the photogrammetric survey based on '99 survey campaign.

3.1 '70s survey data set

For the '70s photogrammetric survey the following documentation was available:

- original compilation on indeformable transparent sheet,
- co-ordinates in local reference system of the 5 control points for the absolute orientation of the stereomodel; the control points was materialised with little iron disks installed on the façade; these signals are still on place, and well visible on the pictures taken with the '99 survey.

The original compilation (see figure 1) consists of : lineaments of the structure, many elevation points uniformly disseminated on the façade and contour line representation of three bas reliefs.

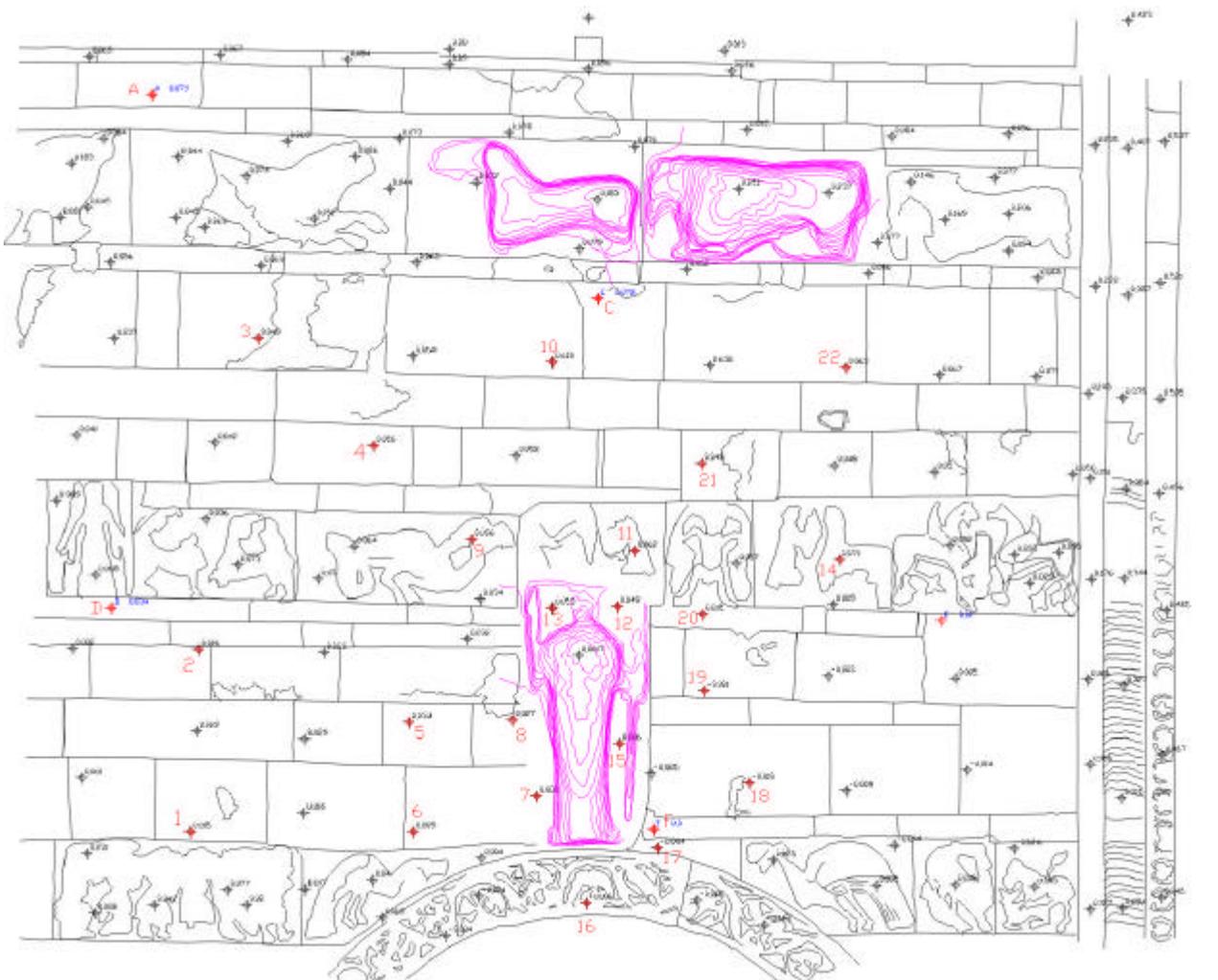


Figure 1

The first set of data was obtained by the transposition in digital form of the original on transparent sheet compilation. This has been done by manual digitising. The system co-ordinates in which the graphic drawing was transformed was determined by means of a co-ordinate transformation based on the planimetric co-ordinates of the 5 control points used for the original stereoplotting. The accuracy parameters of the co-ordinate transformation have been

$$\sigma_x = \pm 0,0011 \text{ m}, \quad \sigma_y = \pm 0,0021 \text{ m}.$$

In figure 1 we can see '70 photogrammetric restitution, now digitised. We can also see the 5 original reference marks (A,B,..E) and 22 other points used like test, as we will explain in the following.

3.2 '99 survey data set

The second data set has been achieved by stereoplotting of a stereoscopic model composed of two pictures achieved by the '99 campaign; these are represented in figure 2.

The stereocompilation was performed by analytical plotter DIGICART 40.

The absolute orientation of the stereomodel was performed using the same control points used for the absolute orientation of the '70s photogrammetric stereocompilation; the parameters of the accuracy of this absolute orientation are the following

$$\sigma_x = \pm 0,0030 \text{ m}, \quad \sigma_y = \pm 0,0042 \text{ m}, \quad \sigma_z = \pm 0,0018 \text{ m}.$$

From the stereocompilation were directly derived in digital form the representation by contour lines of the bas reliefs which were represented in the same way in the '70s stereocompilation.



Figure 2

Besides the co-ordinates of 22 points existing on the '70s data set have been achieved in order to make the following test.

After careful consideration with inspections on the façade we assumed that the sandstone erosion phenomenon which is evident on the bas reliefs is not so apparent on the façade plan.

We hypothesised that visible façade points, not belonging to bas reliefs, are not erosion liable, or, in any case, the erosion entity for them is a size less than bas reliefs points.

To verify this hypothesis

- we chose 22 points taken in '70s photogrammetric restitution, like elevation points,
- the photograms couple of Figure 2 was oriented on the '70s datum: the 22 points chosen was taken by photogrammetric survey.

For the 22 points we made comparisons of differences between Z co-ordinates taken from new model and Z co-ordinates as it was written on '70s traditional stereocompilation.

As accuracy parameter we found

$$\sigma_z = \pm 0,0027$$

Since this value is comparable to absolute orientation parameters, we can tell that the noticed differences are non significant of erosion phenomena.

Since differences on stable points are of about 2 mm, we establish that ± 2 mm is the methodology precision; for this reason we decided to consider significant phenomena up to 1 cm.

4 COMPARISON RESULTS

After testing the data reliability, the photogrammetric restitution, by elevation points and contour lines, was made, with reference to sample test of '70s.

Particularly we studied the bas relief representing S. Ennodio bishop.

It has not been possible to study the relief in its entirety, because in the original '70s survey there were contour lines and elevation points, but not enough on the facade plan near the raised arm of the bishop and between the body and the pastoral staff.

At that time the photogrammetric compilation, even if realised with rigorous methods, was finalised to represent the details, not yet to realise digital models.

The analysis was carried out on two rectangular surfaces, the one relative to the head, the other one to the body of the sculpture.

Digitisation and restitution data have been imported in SURFER 7 environment.

To generate interpolated grids, we chose the geostatistical Kriging gridding method. As grid's step we decided to impose 2 mm x 2 mm.

From '70s and '99 photogrammetric restitution data, two DSMs have been realised.

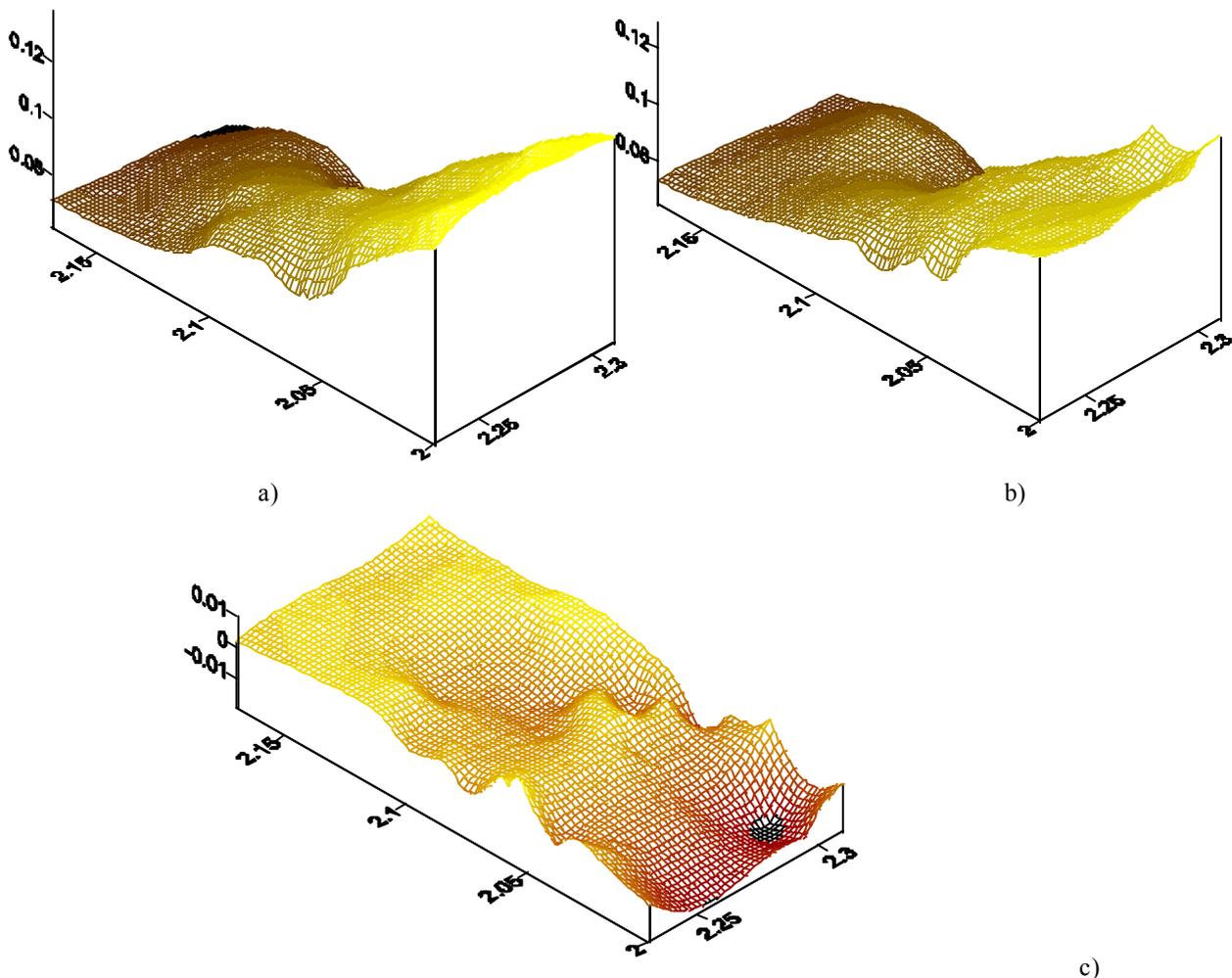
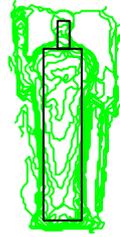


Figure 3 – S. Ennodio bishop head

In figure 3 we can see in a) the DSM made from '70s survey digitisation, in b) the DSM made from '99 restitution and in c) the DSM of differences between b) and a).

The entity of the differences checked is up to one cm.

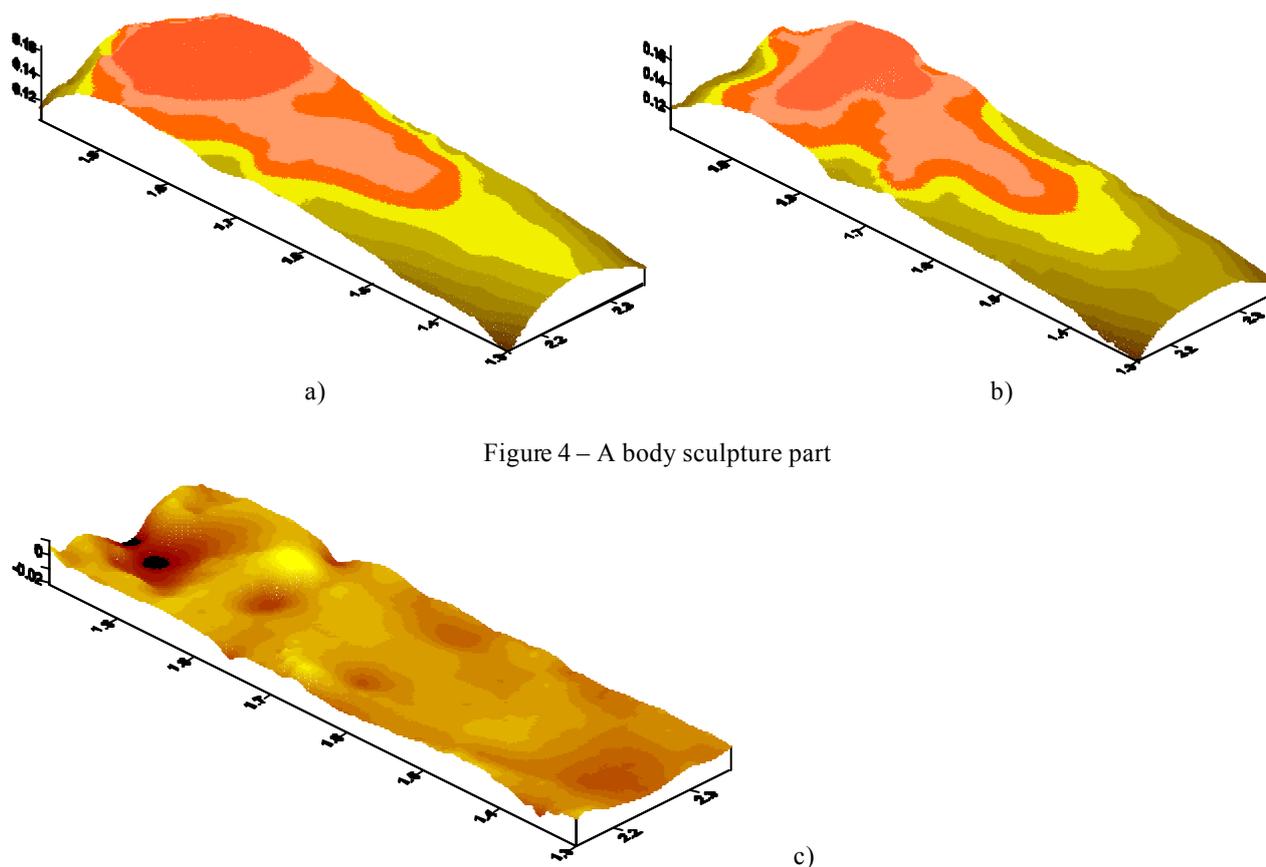


Figure 4 – A body sculpture part

Also in figure 4 we can see in a) the DSM made from '70s survey digitisation , in b) the DSM made from '99 restitution and in c) the DSM of differences between b) and a).

The maximum of the entity of the differences checked is up to 2 cm of erosion.

These are the first results. They will be integrated with other analyses. The first will be a thermographic analysis to realise in order to estimate stone dishomogeneity phenomena.

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