Mediterranean Archaeology and Archaeometry, Vol. 1, No 1, pp. 57-68

INTEGRATED METHODOLOGY FOR MEASURING AND MONITORING SALT DECAY IN THE MEDIEVAL CITY OF RHODES POROUS STONE

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Received: 27-4-2001
Accepted: 4-9-2001

ABSTRACT

The main object of this work is to designate the criteria and methodology for an integrated conservation, protection and preservation of historic cities. The results of the in situ Non Destructive Testing measurements are managed by a G.I.S (Geographic Information System), in order to control the environmental factors that accelerate deterioration of the historic building materials. Infrared thermographs, for the assessment of the humidity distribution within the masonries and the degradation of the stone texture, are supported by the examination of the microstructural characteristics of the stone and the water percolation within the masonry, regarding soluble salts and humidity measurements. It is demonstrated that these methods can be combined into a reliable appraisal of the critical levels of environmental factors triggering damage to the monument(s). The use of the Digital Image Processing technique, allocates the decay mapping of the historic architectural surfaces. Furthermore, the use of Digital Image Processing combined with ultrasonic measurements to deteriorated materials, provides information for the pattern, the extent and the depth of the decay. The collection and presentation of the data arising from the above measurements and analyses, by using an integrated Geographic Information System, for the Medieval City of Rhodes, allows the effective management of historic complexes from environmental risks; particularly moisture in the case of the Medieval City of Rhodes, plays an important role in the transfer, concentration and crystallisation of soluble salts.

KEYWORDS: Non-Destructive, Geographic Information System, Infrared Thermography, Humidity, Salt Decay, Environmental Impact.

INTRODUCTION

The threat to the heritage and particularly to the building materials is rising because of the widespread increase of the atmospheric pollution, urbanisation, industry and tourism. Europeans unite their efforts and resources to protect their Cultural Heritage, which, even though carried on for centuries, at the present suffers rapid deterioration, hardly reversible. The "Conservation of the European Cultural Heritage" is an emerging discipline, comprising an innovative scientific and technical methodology, supported by novel procedures and up to date accomplishments on materials, environmental science and engineering, and informatics. The nature of the problems in addition to the past experience show that in order to accomplish monument's conservation, studies of their historical and cultural context, diagnostic studies, environmental monitoring and impact assessment, and a selection of the appropriate conservation methods and materials, consist the scientific and technical foundation for the proper interventions.

The weathering of monuments may well be considered as an interaction between building materials and active environmental features. Interest focuses on the interface between materials and environment rather than on any intrinsic procedure (Baer, Sabbioni, Sors 1991). The implication of this, in diagnostic and conservation research, is that in addition to techniques of direct intervention to the stone itself, management of environmental factors that initiate stone decay ought to be considered. In a historic city, conservation approaches must be applied on the municipality plans and especially with respect to re-use and rehabilitation.

The example of the Medieval Fortifications of Rhodes, an extended historic complex in a marine environment under different microclimatic conditions, mainly constructed by a highly porous biocalcarenite, suffering as a result of salt decay that generates numerous decay patterns and levels, under various physico-chemical processes on the masonry, is presented. In this work, environmental impact assessment is carried out, in co-ordination with damage analysis so as to outline the criteria for managing the environmental decay factors (Moropoulou et al. 1997, Moropoulou et al. 1999).

EXPERIMENTAL PROCEDURES & TECHNIQUES

In the present work, 5 characteristic sampling points of a total of 19 are presented (Table 1). Decay patterns are semantically related to the micro-climatic conditions.

Aς far as laboratory measurements are concerned, the samples were crushed in an agate mortar. About l00mg of the resulting powder was dispersed in l00ml of deionised water. The aqueous suspension was filtered through a Millipore 0.2μm pore size filter and the filtrate was analysed. Ion chromatography (IC) was performed with a Dionex 4000i instrument, equipped with an AS 11 anion separator column; the fluent was 20 mm NaOH. Ca2+ and Mg2+ were determined by atomic absorption spectroscopy (AAS), whereas Na+ and K+ were measured by atomic emission spectroscopy (AES), (Perkin Elmer 3030 spectrometer). Table 2, in the results section, shows the concentrations of Cl-, N03-, S042, Na+, K+, Ca2+, Mg2+ in the drilling powder samples that were taken in Rhodes. The concentrations are expressed both in weight percentage of the water-soluble fraction of the stone samples and in meq per l00g stone sample. The former to compare the importance of these anions in the samples taken at different locations in the wall, the latter to enable the comparison between the anionic concentrations and the cationic concentrations in the same stone samples. The average of two measurements was used.

The following non-destructive techniques were performed on site:

The techniques of Digital Image Processing, operated on images converted into a complex of numerical data, require a unit of analysis and

Table 1

Sample No	Location	Observations
In the moat		Crust formation / Mixed decay
17a*	Between the Intermediate Tower I and the bastion of Spain – Tongue of Spain	Conservation interventions and hard carbonate crust
12	Intermediate Tower I, northern orientation (on the Tower) – Tongue of Spain to air turbulence	Selective alveolar weathering of the mixed type due
17b	Between the Intermediate Tower I and the bastion of St. George, near the Tower, north-west orientation – Tongue of Overgne	Hard carbonate crusts
9b	Intermediate Tower VIII, south-east orientation (The Theatre of the Moat) – Tongue of Province interventions 9b old - 9b* new material	Mild formation of hard carbonate crust. Recent conservation
Facing the sea		
5	Between the Intermediate Tower X and the Sea Gate, north – east orientation facing the sea – Tongue of Castille	Intense Alveolar weathering

calculation (image processor) both of entry support (input) and exit support (output). The process of conversion from pictorial image to digital image, carried out by means of a telecamera, consists in the sampling of the function f (x, y) according to a square dot matrix and successive quantification of spatial samples codified in the binary system.

In Ultra sound measurements a transducer (transmitter) was placed in contact with the surface to which the pulse, at a variety of low frequencies was transmitted, a receiver (a second transducer) that was placed on the same side (indirect measurement) received the signal at the established distance and gave the measurement of time employed to cover that distance. The velocity of the pulses expresses the distance - time relationship and the depth of different "sonic features". Integrated computerised analysis was performed for stripped and alveolar weathering.

Infrared Thermography (IR) is a measurement technique providing thermal maps. A thermographic system consists of an IR Detector (TVS 2000 Mk II LW) and a Processor (AVIO Thermal Video System). The IR Detector uses germanium, is manufactured by mercury-cadmium-telluride (HgCdTe) that gives a spectral response between 8 and 12 μm wavelengths and requires a stirling cooler system (He gas 99,99%). The IR Detector is connected with a processor that detects the electronic signal, stores it in memory processes it according to a given software and presents it in an LCDS, by the form of a thermograph. The temperature range of the IR Detector spans from -40ΆC to +300ΆC.

For the GIS management of data, a G.I.S. application was developed using Arc/Info software. More specifically, the user has the option to view the available base maps, zoom in/out, pan, etc. Measurements of distance and area can also be performed directly on-screen on the displayed base-maps or in a different approach the user could call up all different images available for a specific test-point and view all of them simultaneously on the screen. Such a visualisation of the data allows quick comparison an evaluation of the specific method for the different test points, or in the second approach of the different imaging techniques for a single point. This in turn allows better strategic planning intervention. The user can select to view the base-maps, along with the test points-locations, information on available data for each test point or finally the full data for a specific test point.

By clicking on a certain test-point the user is prompted to select which of the available data for that point to view. All the actions are driven by point and click menus and made as simple as possibly. The data base architecture is open, i.e. it allows the addition of any number of new spatial data (test point locations, chartographic elements) and non-spatial data (measurement tables, images, text). These can then be functionally seamlessly integrated in the existing database. Besides the best possible organisation of the available information in an easy to use format, the objective of this effort was to identify any possible spatial relationships between the various data (e.g. humidity vs. distance from the underground sewage system), as well as to create a structure, which will be capable of accommodating future data and thus develop into a comprehensive and useful tool for data integration and analysis.

RESULTS & DISCUSSION

It has been proved (Moropoulou, et al. 1995) that humidity and soluble salts distribution within the masonry are correlated among them and in relation to the decay patterns. Hence, the humidity distribution becomes the key element for the environmental impact assessment on historic masonries (Moropoulou, Theoulakis, Chrysophakis 1995; Moropoulou, Koui, Avdelidis 2000).

Infrared thermographs co-ordinated with the results of chemical analysis (soluble salts-ion concentrations and the results of humidity contents permits to evaluate environmental impact assessment on the masonry). Hence it provides information in order to assess incompatible environmental management and to valuate new uses of cultural goods.

Comparison of anionic concentrations along masonry surfaces shows that Cl- anions (Table 2) attains maximum values (>10% weight -% soluble fraction) at sampling points facing the sea, as well as at points 12, 17b (in the moat), where masonry surfaces are oriented towards the most frequent and strong north-western winds from the centre of the Aegean sea; especially at the upper parts of the masonry. Also, SO4_ anions attain maximum values at the same points due to the main traffic lines embracing them.

For the walls facing the sea, the nearby-located port activities pollute the atmosphere in the area, whereas for the walls in the moat (Fig. 1, points 12 and 17b), city centre pollutants are transferred by the northwestern winds. The evidence of gypsum crystals in the relevant points is to be underlined. Concerning humidity contents (in the dry period) a general trend presents an average level between 1-2% in the sea-facing surfaces, suffering from alveolar disease under rapid evaporation while an average between 2-6 % is presented in the case on the surface in the moat suffering more or less by crust formation under mild evaporation conditions. However in positions where recent (9b, 9*b) interventions lead to land filling of the lower parts of the walls along with plantation and watering, humidity contents present over-doubled levels (3-12% for the old stones).

Infrared Thermographs are determined mainly by the humidity contents and distribution among the masonry surfaces, providing information on the differential behaviour of various materials in the masonry

Table 2

	Weight - % soluble fraction							meq / 100g sample						
	Anionts			Cationts				Anionts			Cationts			
sample	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{++}	Mg^{++}
5,1,1	9,700	3,200	1,800					14,967	2,778	1,000				
5,1,2	12,800	4,000	0,700					15,416	2,787	0,315				
5,1,3	12,800	3,700	1,100					16,040	3,016	0,575				
5,2,1	13,200	1,400	6,500					21,211	1,319	3,844				
5,2,2	4,600	0,600	0,800					15,559	1,197	0,935				
5,2,3	14,200	3,300	2,400	0,1253	0,0427	0,7743	0,0265	17,375	2,295	1,080	5,4532	1,0938	38,6395	2,1839
5,3,1	12,400	2,400	6,000					12,757	1,433	2,276				
5,3,2	12,500	2,200	1,500					12,553	1,270	0,555				
5,3,3	13,100	1,800	2,000					15,094	1,187	0,862				
5,4,1	6,100	1,000	16,000					7,925	0,733	7,690				
5,4,2	6,000	7,800	3,200					5,652	4,216	1,116				
5,4,3	7,000	4,300	3,000	0,1039	0,0225	0,434	0,024	6,792	2,377	1,075	4,5225	0,5769	21,6584	19769
9b,1	1,500	10,700	2,000					1,162	4,673	0,570				
9b,2	0,600	3,800	0,700					0,323	1,205	0,135				
9b,3	1,300	4,500	3,000					0,965	1,891	0,821				
9b,4	0,400	0,400	0,500					0,336	0,204	0,161				
9'b,1	0,700	0,900	0,800					0,525	0,356	0,217				
9'b,2	1,400	1,400	1,400					1,533	0,909	0,550				
9'b,3	3,900	2,600	2,400					4,017	1,548	0,906				
9'b,4	0,900	0,700	0,500					0,542	0,264	0,119				
9b1,1	1,000	0,800	0,400	0,055	0,052	0,4684	0,0215	1,534	0,742	0,249	2,3931	1,3309	23,3733	1,7737
9b1,2	1,900	1,400	0,500	0,0277	0,0207	0,696	0,0272	2,213	0,948	0,194	1,2058	0,5317	34,8313	2,8396
9b1,3	3,000	1,900	2,100	0,012	0,011	0,5117	0,0206	2,299	0,851	0,605	0,5225	0,2826	25,5375	1,6996
9b2,1	1,000	0,900	0,700					0,602	0,302	0,160				
9b2,2	0,800	0,800	0,600	0,011	0,0129	0,3755	0,0086	0,298	0,174	0,092	0,4816	0,3324	18,7396	0,7129
9b2,3	0,200	0,200	0,200	0,0433	0,0184	0,8456	0,0249	0,316	0,144	0,098	1,9296	0,4727	42,198	2,0527
9b3,1	0,800	0,600	0,800	0,0228	0,0203	0,5221	0,0218	0,649	0,299	0,241	0,9949	0,5214	26,0543	1,799
9b3,2	0,700	1,000	0,800	0,0135	0,012	0,5149	0,0149	0,308	0,269	0,132	0,5869	0,3091	25,6981	1,2331
9b3,3				0,0171	0,0215	0,6473	0,0127				0,7466	0,5518	32,3041	1,0469
9b4,1	0,400	0,300	0,500	0,0247	0,0219	0,3503	0,0085	0,841	0,397	0,464	1,0761	0,5607	17,4817	0,7057
9b4,2	0,800	0,700	0,600	0,0123	0,0133	0,3326	0,0078	0,359	0,196	0,097	0,5359	0,3403	16,6006	0,6467
9b4,3	0,400	0,500	0,400					0,233	0,174	0,094				
9'b1,1				0,0334	0,031	0,5083	0,0257				1,4533	0,7934	25,3669	2,1204
9'b1,2				0,0253	0,0331	0,5043	0,016				1,022	0,8474	25,1689	1,3229
9'b1,3				0,0472	0,0315	0,5689	0,0172				2,057	0,8062	28,3914	1,4183
9'b2,1				0,0157	0,0157	0,3206	0,0185				0,6872	0,404	15,9995	1,529
9'b2,2														
9'b2,3														
9'b3,1				0,067	0,0354	0,5539	0,0179				2,6419	0,9071	27,6415	1,4769
9'b3,2				0,0498	0,0319	0,5947	0,0174				2,1664	0,8161	29,6795	1,432
9'b3,3				0,0146	0,0297	0,5462	0,0155				0,6359	0,7602	27,3575	1,2628
9'b4,1				0,0314	0,0214	0,3298	0,0099				1,3694	0,5495	16,4586	0,8222
9'b4,2				0,0382	0,03	0,4726	0,0179				1,6656	0,7685	23,5834	1,4754
9'b4,3				0,0253	0,0263	0,4853	0,0199				1,1042	0,6746	24,2173	1,6379

12,1	10,400	10,300	7,500					28,185	15,980	7,626				
12,2	13,600	15,600	2,300					19,772	13,041	1,258				
12,3	14,000	11,400	11,400					17,393	8,398	5,420				
12,4	10,400	10,600	9,900					13,280	7,730	4,653				
12,1,1	14,600	4,100	2,600	0,1626	0,0622	0,4336	0,0261	18,470	2,920	1,185	7,0727	2,1023	21,6369	2,1551
12,1,2	18,400	5,900	4,500	0,182	0,0705	0,5024	0,0174	16,016	2,928	1,450	7,9182	1,7752	25,0712	0,14376
12,1,3	17,900	5,200	5,400	0,1754	0,0745	0,6505	0,0204	13,959	2,300	1,549	7,6311	1,9066	32,4643	1,6637
12,2,1	7,700	1,600	6,800					16,363	1,972	5,350				
12,2,2	18,400	3,200	3,400	0,2163	0,0706	0,356	0,0094	15,669	1,594	1,082	9,4089	1,6056	17,6658	0,7772
12,2,3	12,600	2,400	2,300					10,002	1,104	0,679				
12,3,1	10,900	3,600	8,900	0,1033	0,0499	0,4019	0,0177	9,796	1,664	2,947	4,4954	1,1502	20,0555	1,4563
12,3,2	6,300	2,000	17,500	0,0593	0,0539	0,3165	0,0187	4,690	0,863	4,857	2,5814	1,3786	15,7943	1,5461
12,3,3	6,300	2,000	17,500					4,690	0,863	4,857				
17'a1,1	0,300	13,100	0,300					0,256	6,600	0,085				
17'a1,2	0,400	31,400	0,000					0,315	15,872	0,000				
17'a1,3	0,300	0,700	0,000					0,158	0,202	0,000				
17'a2,1	0,300	0,200	0,400					0,441	0,162	0,199				
17'a2,2	0,300	1,000	0,000					0,176	0,324	0,000				
17'a2,3	0,200	0,700	0,000					0,152	0,333	0,000				
17'a3,1	0,100	0,300	0,000					0,169	0,238	0,000				
17'a3,2	0,300	32,900	0,200					0,334	19,213	0,060				
17'a3,3	0,200	29,900	0,000					0,260	16,488	0,000				
17'a4,1	3,400	26,000	1,700					3,633	17,029	0,729				
17'a4,2	8,700	2,500	1,300					5,299	0,863	0,292				
17'a4,3	4,300	16,100	0,800					4,559	11,022	0,313				
17b1,1	10,000	18,500	0,600	0,1418	0,0925	0,4106	0,0134	11,340	12,041	0,236	6,1706	2,3677	20,4916	0,1055
17b1,2	6,300	17,000	0,300					17,466	20,356	0,217				
17b1,3	19,200	22,600	0,800	0,3562	0,141	0,475	0,0163	19,621	13,226	0,219	15,4964	3,6064	23,7032	1,506
17b2,1	7,600	4,700	8,400	0,1462	0,1004	0,7752	0,016	7,962	2,840	3,237	6,3623	2,5686	36,6642	1,3236
17b2,2	7,200	3,600	1,200	0,0947	0,622	0,3573	0,0062	4,666	1,466	0,314	4,1234	1,5913	17,6301	0,6796
17b2,3	3,500	4,500	0,000	0,0598	0,0509	0,4465	0,0122	2,286	1,674	0,000	2,6013	1,3037	22,5309	1,0061
17b3,1	0,400	0,900	0,000	0,0175	0,0169	0,789	0,0121	0,417	0,502	0,000	0,7627	0,4658	39,3757	1,0017
17b3,2	0,300	3,900	0,000	0,0076	0,011	0,4824	0,0076	0,340	2,687	0,000	0,3341	0,2623	24,0757	0,6318
17b3,3	0,300	5,000	0,000	0,0159	0,0154	0,3953	0,0119	0,212	2,437	0,000	0,6921	0,3942	19,7268	0,9817
17a,1,1				0,0066	0,0076	0,322	0,0076				0,2905	0,1952	16,0699	0,6279
17a,1,2				0,0468	0,0121	0,4536	0,0117				2,0369	0,3116	22,6376	0,963
17a,1,3				0,0205	0,0161	0,3825	0,0142				0,6959	0,4139	19,0666	1,17
17a,2,1				0,0131	0,0162	0,3509	0,0131				0,5699	0,4667	17,5129	1,0778
17a,2,2				0,0084	0,0069	0,3861	0,0103				0,366	0,2278	19,2663	0,6552
17a,2,3				0,1341	0,0146	0,351	0,0102				0,6998	0,374	17,5173	0,8422
17a,3,1				0,0068	0,0187	0,4583	0,033				0,3001	0,4769	22,8719	2,7164
17a,3,2				0,0124	0,224	0,3621	0,0339				0,5431	0,5748	19,0677	2,7941
17a,3,3				0,0098	0,0167	0,4963	0,0291				0,43	0,4262	24,4197	2,3991
17a,4,1				0,08	0,0258	0,5926	0,0229				3,4798	0,661	29,5749	1,666
17a,4,2				0,0629	0,0218	0,4294	0,0164				3,6069	0,5563	21,4273	1,357
17a,4,3				0,065	0,026	0,615	0,0165				3,6972	0,6649	30,6666	1,5216

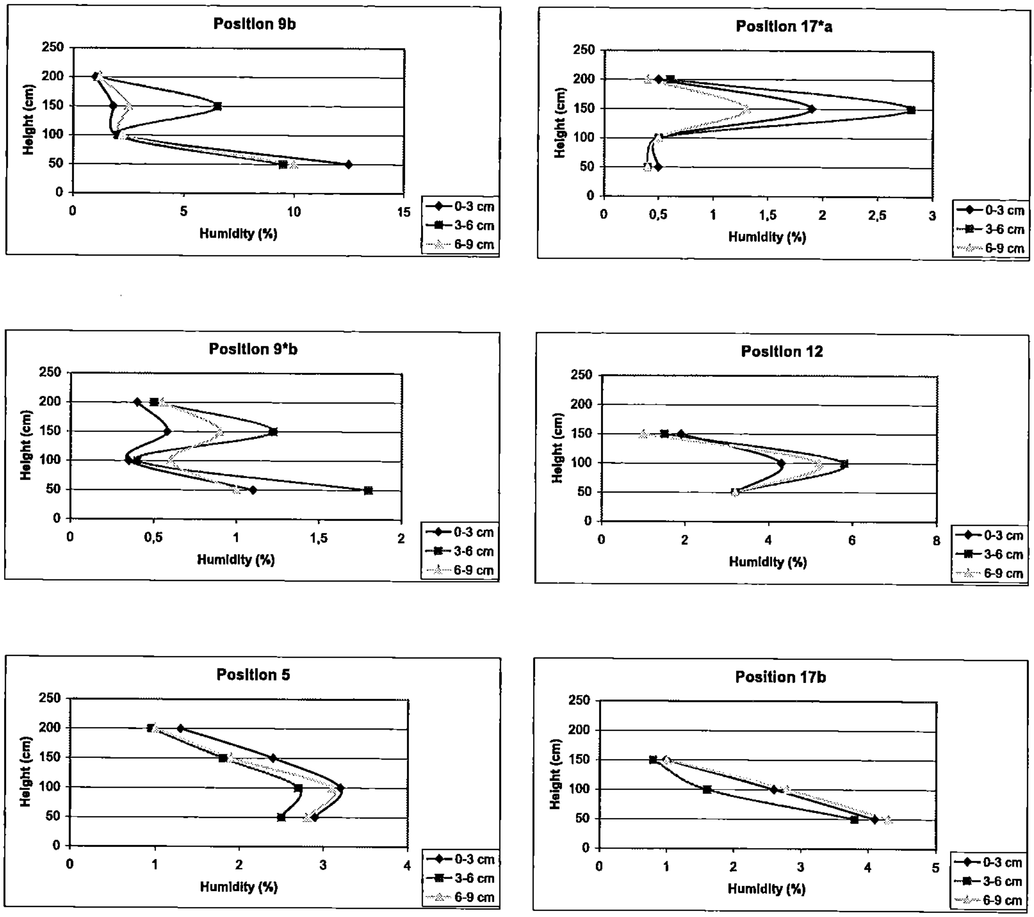

Figure 1

and on the impact of the microclimatic variations on the same building material, since the water evaporation cycles are controlling the weathering effects in porous media.

The Digital Image Processing (DIP) results show the characteristic distribution pattern of the weathering forms, when the microstructural and textural characteristics of weathered stone are used as interpretation criteria. The prevailing weathering profiles of the alveolar disease levels in evolution, in a way that they reflect the light towards more grey shades, are discernible by false colours towards black in the sequence of higher damage levels. Image classification to the level of more or less severe alveolar damage, is possible. This is in contrast to the hard crust formation that due to its coherent microcrystalline calcitic surface exposed to the light, attains reflection towards the lightest shades of grey and is distinguished by false colours towards yellow, hindering however a potential advanced damage level due to the internal relaxation zone that it develops. Biological attack to the hard carbonate crust entails disaggregation of the external calcitic surface, resulting to higher grey levels, not as high though as in the case of alveolar disease. The substrate, i.e. whether it concerns hard crust or mere the porous building stone, determines the restitution of biological crust by grey-ochre or maroon tonalities. The same contrasts distinguishes compact (new) to dissaggregated porous stones (old) and in generally incompatible to historic restoration materials.

The visualisation of digitally processed images (Figure 3) of weathering and building materials permits the allocation of conservation interventions, i.e. conservation planning.

As it resulted from the decay analysis, the main necessary conservation interventions are:

■ Conservation substitution for old stones by compatible new ones. Mapping permits the allocation of incompatible substitutions and in co-ordination with porosity measurements or in situ assessment, allows for the choice of the proper quarry for compatible new stones excavation. The criterion to be met is compatibility among old and new stones concerning compactness of cementing material and pore systems. Lithotypes mapping along the walls permits the proper choice per surface area according to the lithotype by which it is constructed.

■ Reconstruction and filling of washed out joint mortars by compatible restoration mortars. Mapping permits reallocation of the most damaged areas to be reconstructed as well as the washed out joint mortars that under the exerted stresses produce masonry pathology (fissuring, cralls, etc.). The criterion to be met is compatibility of restoration mortars, with the porous stone and the historic ones. The advanced caveneous alveolar disease of the porous building stones due to the incompatible cement mortar of the Italian restoration (in the middle-war period) permits to discern incompatible mortar joints in order to intervene properly.

■ Consolidation of disaggregated porous stones due to advanced alveolar disease. Mapping permits the allocation of masonry surfaces areas damaged by alveolar disease due to salt crystallisation, where consolidating materials should be induced by proper techniques into the masonry. Integrated Computerised Analysis might be used to assess and evaluate consolidation pilot intervention on the masonry according to the results of the relevant consolidation study.

■ Integration of stone cavities. Mapping permits as well the allocation of very corroded stones where big cavities have to be filled. In that case artificial stone could be produced by proper, very dense mortar, comprised by crushed porous stone as aggregate.

■ Mechanical connection of bearing building stones units in characteristic architectural elements (arches, gates, etc.) by compatible metal joints to the very aggressive, corrosive marine environment. In that case iron, even steel bars should be excluded due to the high salinity of the atmosphere while titanium joints are suggested.

■ Cleaning of facades and especially marble decorations from the black crust is indicated by the relevant allocation and mapping. Proper materials and techniques have been already suggested by a relevant pilot project. Biological crust should be cleaned only in the case of buildings under restoration whereas hard carbonate and biogenic crust should be left intact on the masonry. Any intervention on masonry crusts would produce a retreat in the facade due to the ablation of the outer surface of the crust, which is weakened underneath its hard exposed end.

Devaluating cultural heritage derives from the inevitable marine atmosphere, but as well from town planning related uses and incompatible environmental management. Environmental loads can be visualised in their spatial distribution in the raster map (Figure 4), classified as follows:

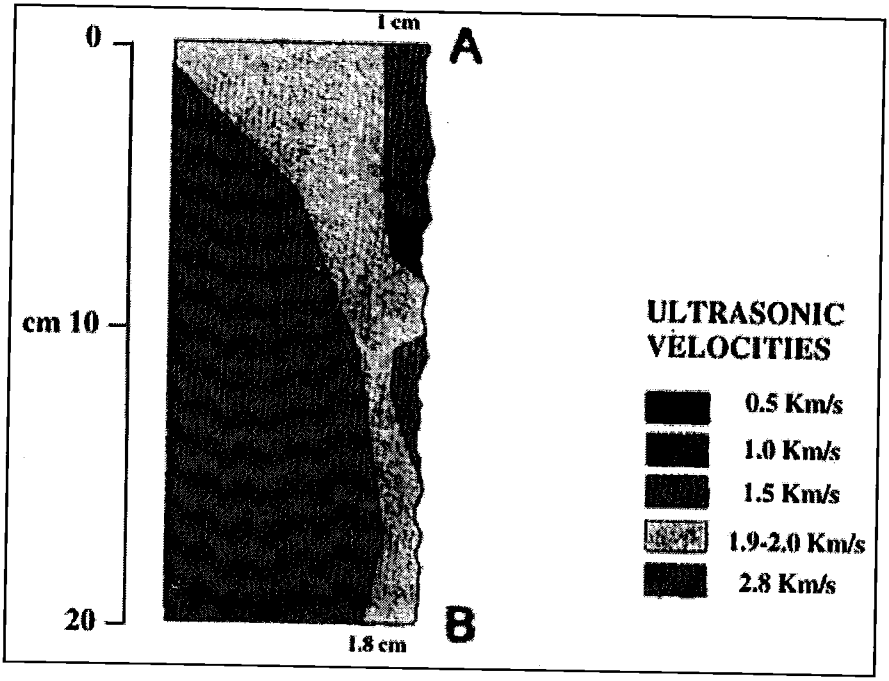

Figure 2

Environmental loads:

- Salt spray sources (blue)
  * sea borders, wind directions and frequency
- Pollution sources (red)
  * main traffic lines, commercial port, city centre
  * marina and parking
- Humidity sources
  * Negative management i.e. land filling, plantation and watering (green arrows)
  * Positive management (like by drainage and cleaning of plantation etc. (brown) and by introduction of new uses, as cultural uses etc. (yellow))
  * Infrastructure system (like sewage system etc. (dark grey lines)). Their design has to manage humidity positively

In order to tackle environmental loads, the following management interventions are suggested, concerning:

Active management (directly to environmental sources):

- Pollution sources:
  * allocation of the pollutants sources through comparative examination of the accumulations on the monumental surfaces employing isotope analysis
  * monitoring of the pollutants and aggregation emitted from every possible source
  * elimination of the pollutants by proper urban planning, measures and regulations concerning the responsible sources (port, traffic, parking, central heating, tourism activities etc.).
- Humidity sources:
  * Estimation of critical humidity contents and localisation of sources
  * Evaluation of environmental works (infrastructures, land fillings, planting, watering, etc.) as negative or positive management of humidity sources.

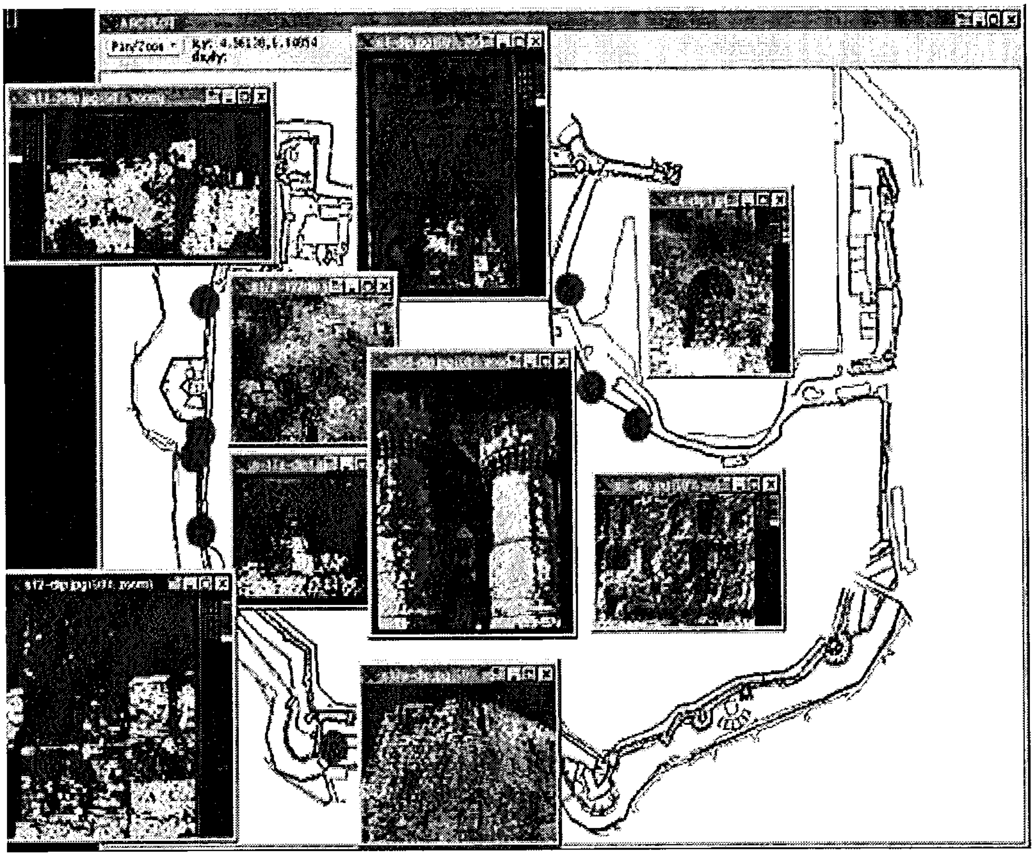

Figure 3

* Elimination of humidity sources under critical humidity contents (drainage, cleaning of plants, maintenance, etc.)

Preservation of the integral cultural and natural Environment:

- Active : Environmental management
- Introduction of new uses (rehabilitation) supporting, sustaining and maintaining environmental management. Suggested uses are recreational and cultural uses, controlled tourism activities, etc. Elimination improper uses like the ones assessed as having negative impact to the monumental structure and surface.
- Proper urban planning and plan of land uses. Passive Management (indirectly - Preservation of materials and structures):
- Diagnosis weathering (decay) mapping and environmental impact assessment
- Conservation planning and implementation
- Monitoring, control and maintenance interventions regarding materials, structures and ongoing environmental management.

The concept of sustainable development centres on the various treats to and problems facing heritage and cultural identity and aims to achieve harmonious and balanced growth of social, economic and cultural values. Since modern society is becoming increasingly concerned about its heritage and is now making greater social use of it, the consideration of culture as an instrument for economic

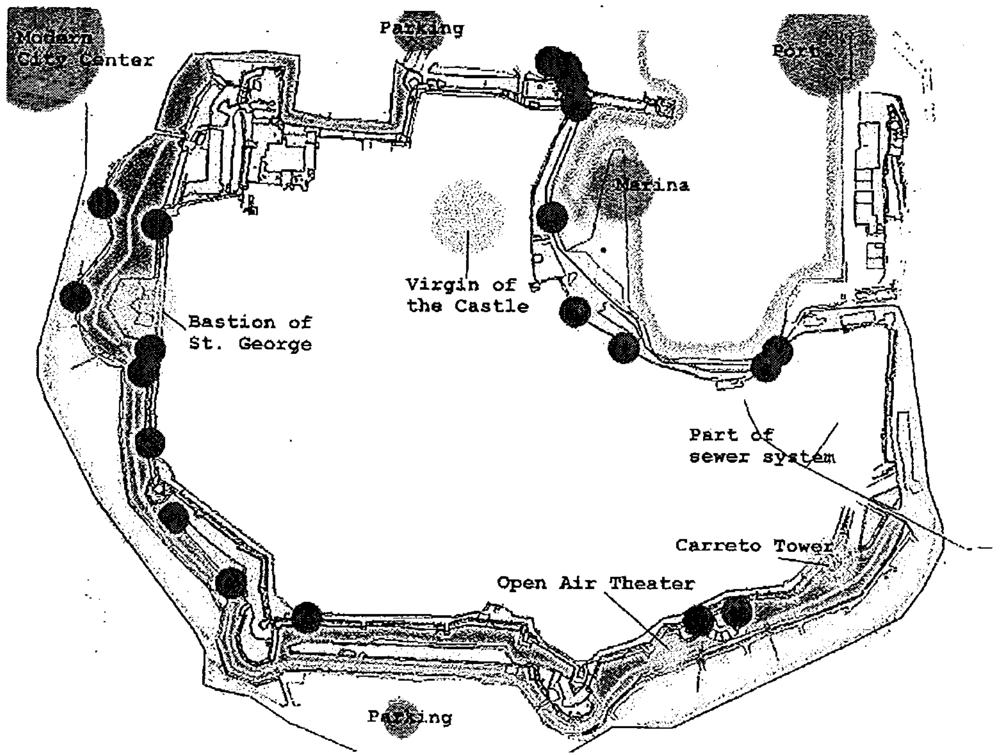

Figure 4

development should be accepted and developed. It should therefore be integrated into the processes of strategic planning and territorial revitalisation.

Tourism may be attractive for local development but its advantages and disadvantages, costs and benefits should be carefully studied. The search for management models and consensus policies leading to sustainable development alongside quality tourism experiences is a real demand and a challenge. In addition, the processes of economic change and global restructuring mean that more and more space is given up to social and recreational uses. This could lead to excessive utilisation of resources unless consideration is given to the direct and indirect impact of such tourist activities.

The impact of tourism to the physical, socio-economical, political and cultural environment has to be studied for the avoidance of damage to our heritage based on proper management of resources and visitors.

CONCLUSIONS

Integrated environmental planning ought to be attempted according to environmental, functional, material, structural and social criteria with the objective of eliminating the negative impact on the monumental building and the historical complexes as a whole. This could prevent further damage and maintain the necessary conservation level, while the historic site, city or complex would be revitalised through new uses and its role would be strengthened.

The development of the database, managed by a GIS is used to create alternative suggestions relating to conservation and planning strategies.

The results will give an input for decision support on the subject of historical preservation planning policies. This expert system could be used as a pilot one for "Historic Complexes', Cities' or Sites' Environmental Management towards Conservation". Possible comparisons among historical complexes might assess and improve the validity of the pilot plan.

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