ASSESSING THE CLEANING METHODS ON THE LIMESTONE FAÇADES IN THE FORMERLY WORKERS HOSPITAL OF MADRID, SPAIN

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INTRODUCTION

The formerly Workers Hospital was designed by architect Antonio Palacios in the Northern enlargement of Madrid at the beginning of the 20th century. The building and its surrounding wall are mostly built with limestone masonry. It remained abandoned almost during 25 years, and the Government of Madrid purchased the property at the beginning of the eighties of the last century. It commissioned the building restoration, and the works were carried out between 1984 – 1986.

The main decay forms that exist on the stone facades are related to soiling processes, with the development of black crusts in some specific areas. The main causes responsible for this soiling are the urban environment that surrounds the Hospital (Figure 1) -with intense traffic-, the façades and the wall design with many set backed elements that makes very difficult their washing by rain water, the rusticated finishing ashlars and the own passage of time.

Fig. 1. General view of the Formerly Hospital, façades of the northwest body, church and surrounding wall.

METHODOLOGY

Four different stone cleaning techniques[1] have been tested, and their effectiveness assessed by means of determining the chromatic parameters of the limestone, before and after been cleaned. The global index of colour change (ΔE^*)[2,3] has been calculated, compared to the colour of the building limestone naturally washed by rain; in this specific case the basement limestone was selected.

The suitability of these methods has been also tested through X-ray diffraction (XRD), ion chromatography and scanning electron microscopy (SEM). The criteria selected for the suitability are related to the presence or absence of alteration products (i.e. salt formation) or changes developed on the stone superficial texture. The cleaning methods have been tested *in situ* on the limestones of the middle part of the surrounding wall, as it is the area that presents the highest soiling levels (Figure 1). For the techniques assessment, the chromatic parameters of the stone have been measured before and after its cleaning using a spectrophotometer (Minolta CM-2002). The cleaning methods tested correspond to alkaline gels-based system sodium and potassium hydroxides), pressure hot water jet (60ºC), glass microspheres blasting with a grain size ranging from 50 to 100 micrometers and a water:microspheres ratio of 1:4, and a latex-based product with 10% of EDTA (etilen-diamin-tetra-acetic) and ammonia.

RESULTS

While the sodium hydroxide-based product effectiveness is acceptable, the one based on potassium hydroxide offers not so good results, even induces salt formation on the stone surface. The effectiveness obtained with glass microspheres blasting is considerable because it removes the black crusts and it does not generate by-products. Nevertheless, this method affects the superficial texture of the stone. The latex method and the pressure water jet do not provide acceptable results, presenting the cleaned surfaces slight modifications, and besides, the latex remains are not easy to be completely removed (Figure 2).

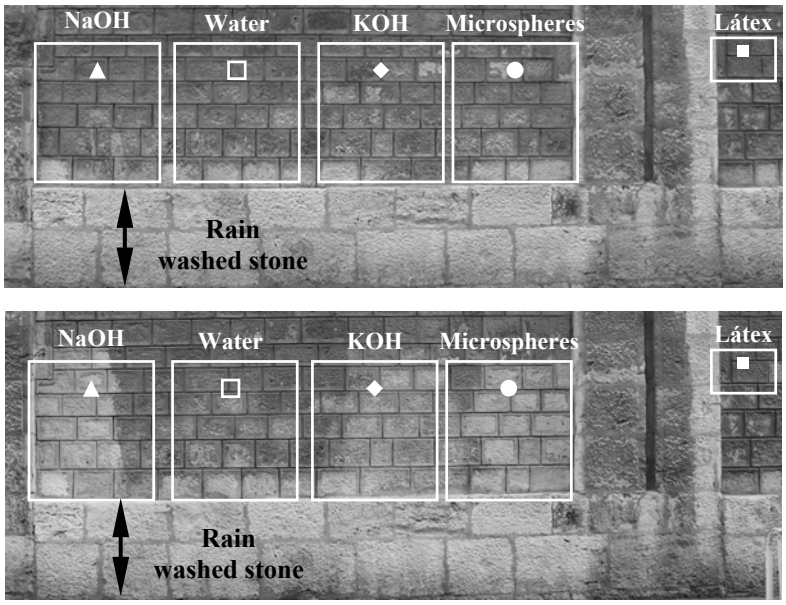

Figure 2. Wall stones appearance after (above) and before (below) the cleaning methods tested.

Table 1 shows that alkaline gels and microspheres provide the highest limestone luminosity (L* = 72,06; 67,26 and 63,96 respectively), values that are close to those obtained from rain washed stone (L* = 80,56). The yellow index of the limestone before its cleaning with these techniques (YI = 13,37; 15,71 and 16,54) also presents the nearest values to the wall basement limestone (YI = 15,6). The less yellow and white indices modification (with respect to natural washed stone) with any cleaning method, the better the cleaning method. On the limestones tested with the NaOH alkaline gel based treatment, a white index of 20,8 was achieved, very similar to the one measured on rain washed stone (WI = 21,83).

The latex method and water pressure jet are not so effective, presenting the treated limestone similar chromatic parameters respect to those of the stone before cleaning. According to the global index of colour change, the lower the measured values before the cleaning, the more effective the method. This is due to the fact that with its application the colour of the cleaned stones will be more similar to that of the natural washed stone colour.

The lowest ΔE^* value measured before the cleaning is accomplished by the NaOH based gel (ΔE^*= 8,43). On the limestones cleaned with the water pressure jet and latex methods, their ΔE^* decreased slightly (30,74 and 27,79 respectively).

		L*	a*	b*	ΔE*	YI	WI
Rain washed stone		80,56	1,22	9,07		15,6	21,83
NaOH	Before	51,2	1,93	7,46	29,41	18,44	5,4
	Increase	29,36	-0,71	1,61		-2,84	16,43
	After	72,39	1,4	7,02	**8,43**	13,37	20,8
	Increase	8,17	-0,18	2,05		2,23	1,03
KOH	Before	42,33	3,63	12,56	38,46	33,59	-4,45
	Increase	38,23	-2,41	-3,49		-17,99	26,28
	After	69,06	2,3	7,93	**11,61**	15,71	15,15
	Increase	11,5	-1,08	1,14		-0,11	6,68
Micro spheres	Before	47,54	2,39	9,64	33,05	24,62	0,43
	Increase	33,02	-1,17	-0,57		-9,02	21,4
	After	66,86	1,92	8,22	**13,74**	16,54	12,46
	Increase	13,7	-0,7	0,85		-0,94	9,37
Water	Before	46,18	3,02	11,41	34,51	29,24	-2,5
	Increase	34,38	-1,8	-2,34		-13,64	24,33
	After	49,86	2,54	10,03	**30,74**	22,55	1,95
	Increase	30,7	-1,32	-0,96		-6,95	19,88
Latex	Before	44,82	2,78	9,51	35,78	25,27	-0,17
	Increase	35,74	-1,56	-0,44		-9,67	22
	After	52,89	2,22	11,46	**27,79**	26,62	-1,48
	Increase	27,67	-1	-2,39		-11,02	23,31

L*: Luminosity
a*: Red hue
b*: Yellow hue
$\Delta E^*: (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$
YI: Yellow index
WI: White index

Table 1. Chromatic parameters measured on the limestone before and after the cleaning techniques tested, compared to the values of the rain washed stone.

CONCLUSIONS

Attending to ΔE*, ΔYI and ΔWI, the most effective cleaning techniques have resulted the alkaline gels application and the glass microspheres blasting. Both of them introduced very slight colourimetric modifications respect to those measured on the naturally washed limestone. The KOH based gel induces the formation of salt by-products and the microspheres system affects the superficial texture of the limestones. Therefore, the most suitable method for the limestone cleaning used in the formerly Workers Hospital is the NaOH based alkaline gel. Nevertheless, we should not rule out the microspheres method, although the pressure should be lowered.

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