Durability of a ventilated stone facade: A case study of a limestone facade affected by the corrosion of the anchorage system

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INTRODUCTION

One of the most important engineering characteristics of a stone for cladding is related to its anchorage strength.

Unsuccessful applications show the need for:

- Anchorage strength tests according to each type of fixing system selected to assess how stone will behave.
- Suitable anchor selection for each project.

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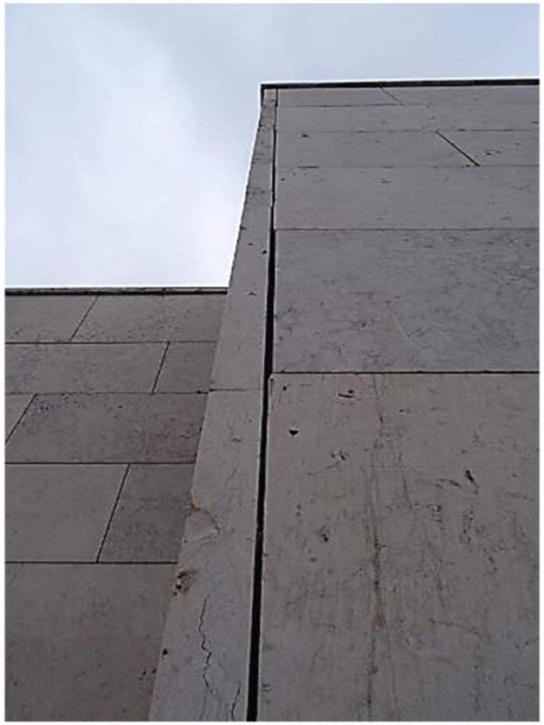
INTRODUCTION



The present study aims understanding causes of the corrosion of an anchorage system of a ventilated stone façade cladded with the Portuguese limestone “Lioz”.

Lioz limestone ventilated façade

| 20 years in service

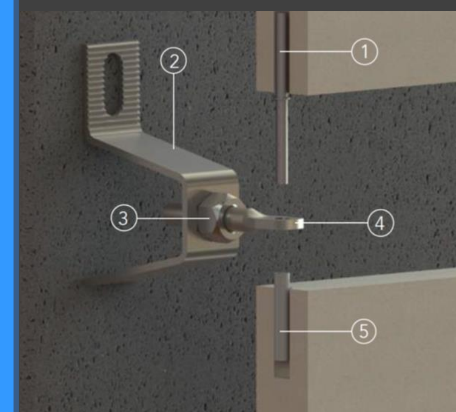
| Public building

| Low maintenance = light cleaning on year 10 and 20

| Dowel-hole anchor stainless steel system

| Enclosure support = concrete walls

| Identification of fissures, ruptures, detachments



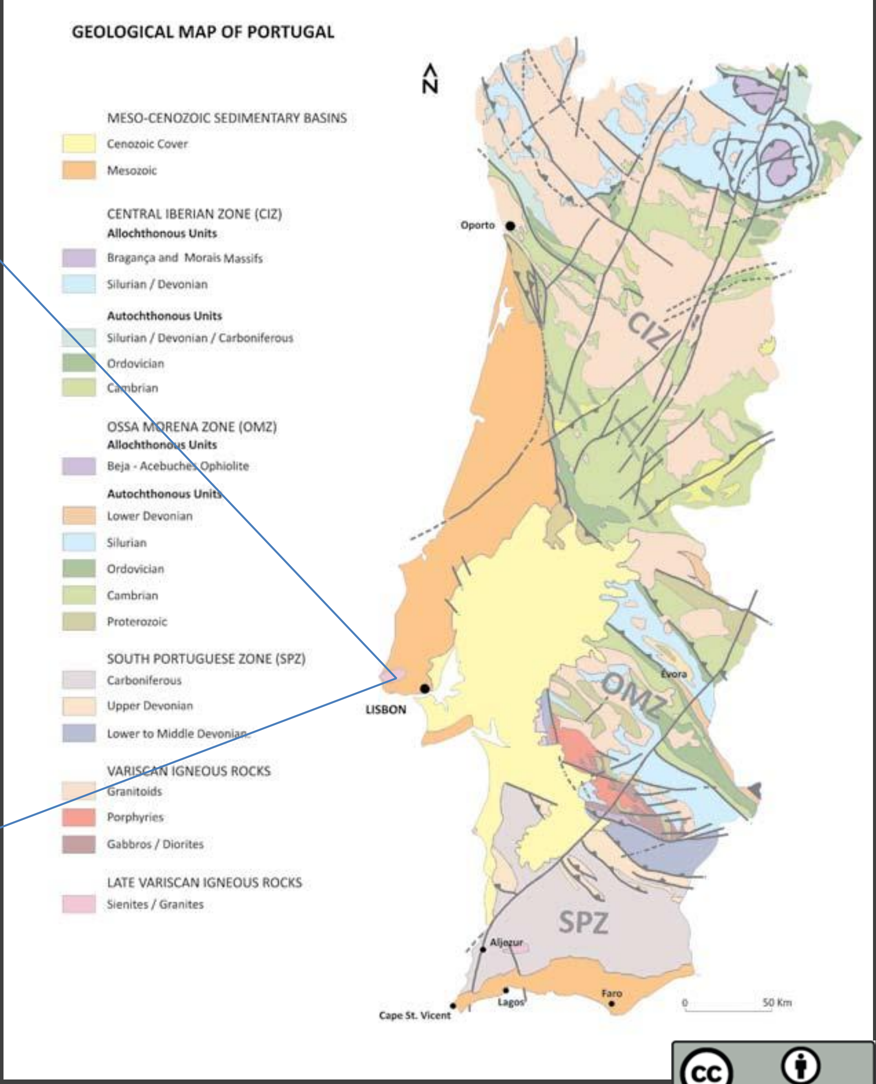
MATERIALS
Stone Materials

Lioz limestone

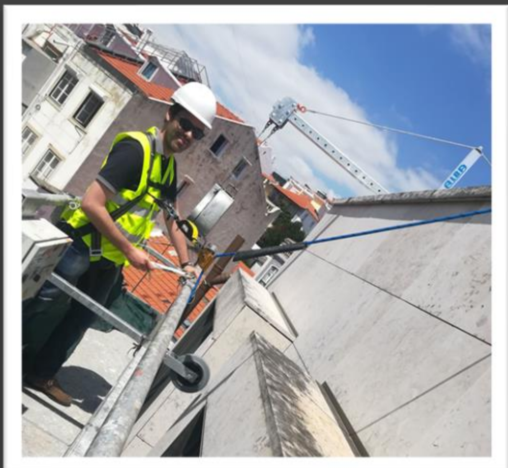
Stone Material	Physical Mechanical Properties	
	1. Compressive Strength (MPa)	103
	2. Compressive strength after 48 frost cycles (MPa)	103
	3. Flexural Strength (MPa)	14.4
	4. Apparent Density (kg/m^3)	2700
	5. Water Absorption (%)	0,1
	6. Open Porosity (%)	0,3
	7. Thermal expansion coeffitient (X 10 -6 per° C)	3,3

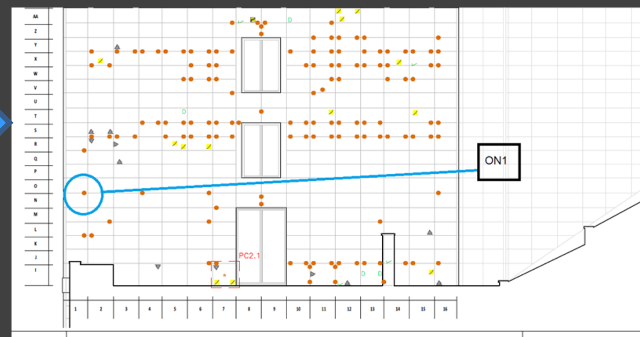
ORIGIN : Pero Pinheiro – Sintra (Lisboa)

MACROSCOPIC DESCRIPTION: Microcrystalline beige limestone, coarse, bioclastic and calciclastic.



METHODOLOGY
Inspection





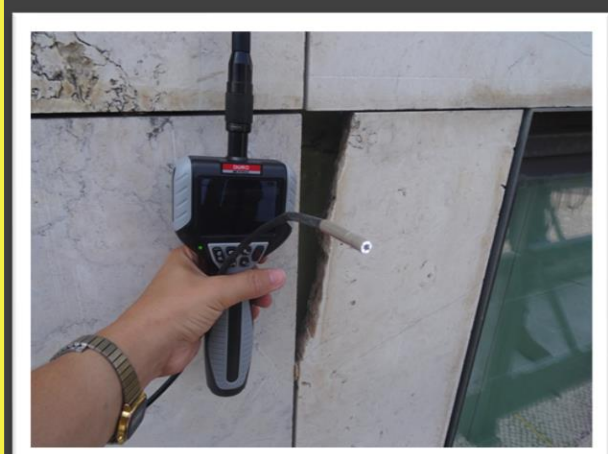
MAIN ACTIONS

|Site-inspection

|Pathology identification and mapping

| Non-destructive borescope analysis of the metallic anchors

| Quantitative chemical composition analysis | FRX



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RESULTS & DISCUSSION

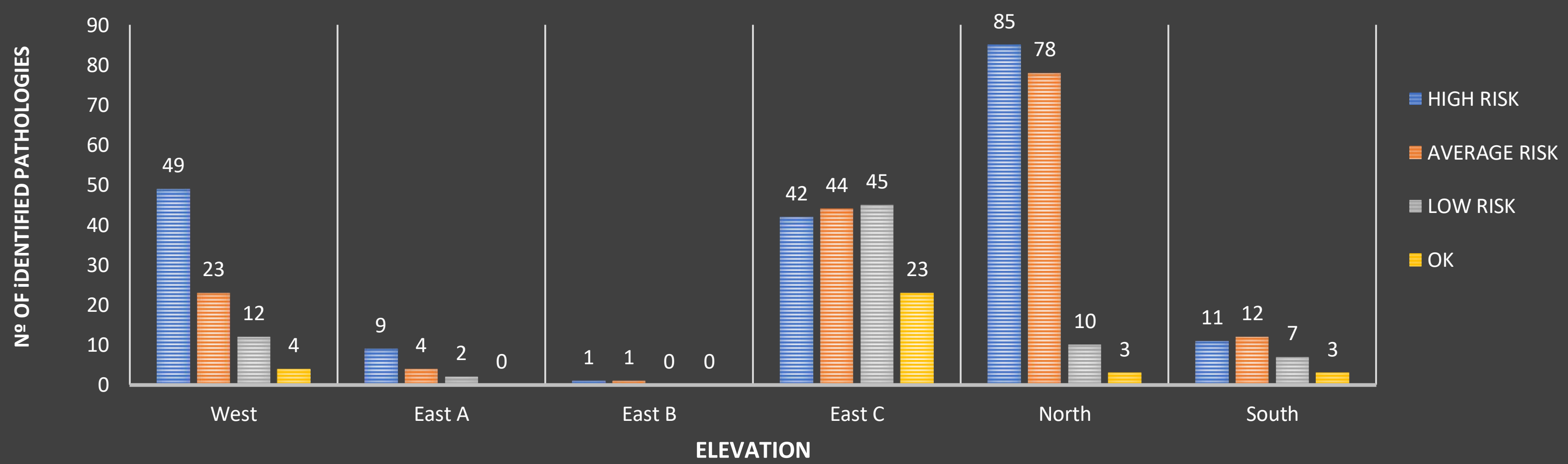
Site Inspection - visual & boroscopic

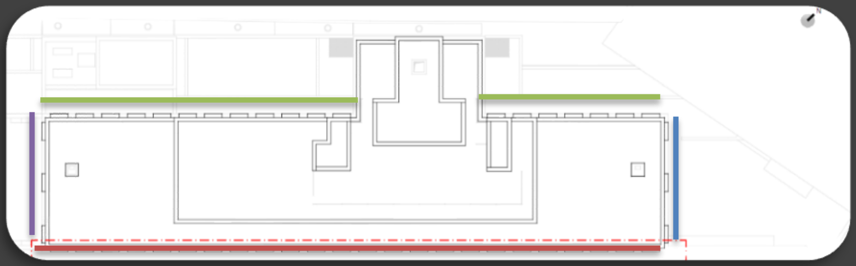
| 48% issues depicted high risk @ North elevation

| 27% issues depicted high risk @ East elevation

| High risk is linked to a higher probability of cladding failure

| High risk = anchoring system with corrosion + stone slab with critical pathology





North
South
East
West

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RESULTS & DISCUSSION

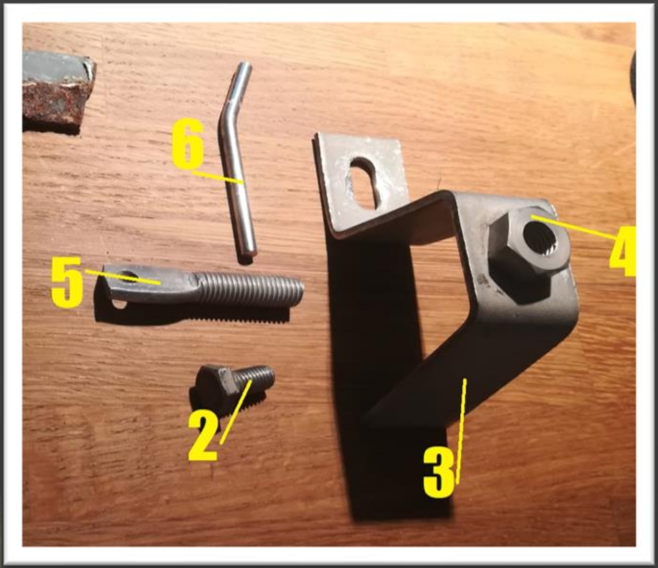
Several anchor items = diferent steel composition

| **#6** – A2/304 steel suitable for standard environtmental conditions

| **#5** – A4/316 steel improved compostion for agressive environmental conditions but not reisistante to seawater.

| **#4** – A1/303 steel good workability but only suitable for mild environmental conditions

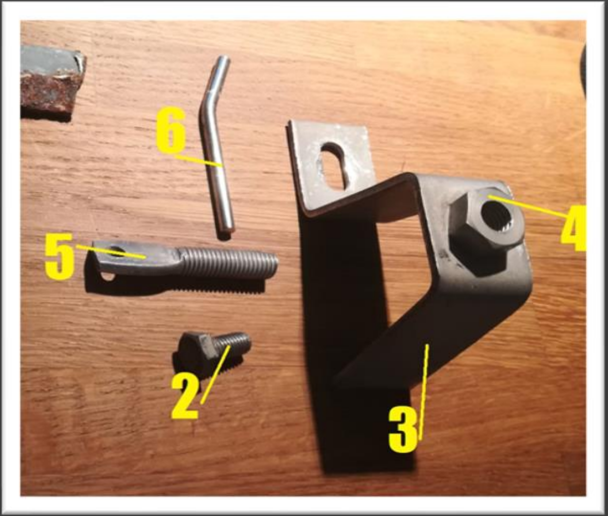
| **#3** & **#2** – A3 similar to A2/304 with stabilized conditions



Anchor system item ref.	Elements (%)									Steel type	Corrosion resistance
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu		
# 2	0.06	0.42	1.6	0.036	0.015	18.2	0.28	9.4	---	A3	++
# 3	0.05	0.38	1.7	0.028	<0.008	18.5	0.30	8.7	---	A3	++
# 4	0.04	----	1.6	----	0.33	17.3	0.44	8.7	0.42	**A1**	-
# 5	0.04	0.62	0.88	0.029	<0.008	17.3	2.2	10.5	> 1.9	A4	+++
# 6	0.10	0.59	1.7	0.029	> 0.04	19.5	0.54	7.8	---	**A2**	+

CONCLUSIONS

- Anchor item #4 is made of A1 stainless steel which is highly unsuitable for the load + slab size + environment.
- 60% of #4 anchor items present severe pitting corrosion = environmental+ stress + poor installation combination.
- Most stone drilling was made on site = poor work quality.
- 98% of the inspected anchor items show corrosion at several levels between severe and mild.
- Aprox. 60% of the inspected stone slabs were classified has high risk for collapse. Replacement was recommended.
- All anchor items should at lest made of A4 stainless steel = better corrosion and mechanical performance.
- Corrosion of metals is a kinetic process, which occurs at a certain speed and which allows, once a critical degradation level is reached, failure at the anchor and consequent rupture of the Lioz slab. Failure of the anchor elements will occur by reducing the cross section of the most weakened item.



THANK YOU

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