

Ryan McDonnell
Haringey Council

29TH MARCH 2023

REFERENCE: DM/23007/001

Capital Projects and
Property
Haringey Council
5th Floor, Alexandra
House

Dear Ryan McDonnell,

Haringey Civic Centre – Pre-cast sample Petrographic Analysis

Please find attached the report on the Petrographic analysis of a pre-cast cladding sample removed from Haringey Civic Centre.

The pertinent points are detailed below.

Saturation Coefficient = 0.95 (note: if saturation coefficient >0.8, the mortar/stone is at risk from ice/freeze-thaw action).

Compressive Strength = 15 – 16MPa (comparable to the **early 7day** strength of OPC but much less than 28-day strength).

The grading curve for the aggregate, shows that the aggregate is well graded and is essentially suitable for a Pre-Cast stone of medium grain texture.

Phenolphthalein turns from clear to purple-red in contact with alkaline surfaces. The photomicrographs indicate that there is uncarbonated lime [$\text{Ca}(\text{OH})_2$ Portlandite] mainly from hydrated cement compounds (alite and belite), plus some uncarbonated 'free lime' from the original cement clinker.

This can be deduced from the value of pH12 for the cast stone surfaces (which should be about pH8 after full carbonation), indicating significantly more lime present within the cast stone matrix than if it were fully cured. However, the top surface of the cast stone is mostly carbonated down to depth of about 1mm (no red colouration of the surface was seen with phenolphthalein).

Analysis results give **4.4% active lime** in the binder (**indicating it is 95.6% carbonated**). There is generally about 2.5% free lime $\text{Ca}(\text{OH})_2$ in white cement clinker, so much of the uncarbonated lime must be attributable to hydrated but uncarbonated alite and belite, despite any free lime from the clinker.

It is quite likely that the uncarbonated nature of the cast stone is the main cause of any deficiencies in its performance because it will not be as strong or as dense as it might be if fully cured/carbonated (its compressive strength is around **16MPa** when it should be perhaps around 30MPa).

Slow, non-homogenous carbonation of cement can lead to 'differential carbonation' which produces differential stresses at a micro-scale within the cement matrix, i.e. between carbonated and uncarbonated zones and between matrix and aggregate grains, often resulting in micro-cracking. Micro-cracks can be exploited by water ingress and thus freeze-thaw action (**saturation coefficient of the cast stone = 0.95, suggesting it is at risk from ice action**), thus further increasing fracturing. In addition, non-homogenous carbonation causes greater problems if the water: cement ratio was perhaps too high.

As with lime, carbonating cement matrix loses water and may shrink. Migrating water from the carbonation reactions can lead to solution loss of material and fracturing due to ice action, both of which would increase the porosity of the cast stone but reduce its flexural strength and elastic modulus.

Conclusions

From the test results the mortar mix used to construct the pre-cast is essentially suitable for a pre-cast stone of medium grain texture.

Deficiencies that have occurred during the mixing of the mortar and curing however have resulted and contributed to failure and on-going deterioration of units.

Detection of uncarbonated lime is likely to be the cause of the following deficiencies:

- Risk from ice/freeze-thaw action.
- Low compressive strength around 16MPa. Expected strength around 30MPa.
- Micro cracking.
- Reduced flexural strength and elastic modulus.

Due to the inherent deficiencies, it is not recommended to carry out mortar repairs to pre-cast cladding as the substrate is prone to failure resulting in loss of adhesion, de-bonding and detachment of material.

Mortar repairs do not provide any structural benefit or long-term weathering properties.

The porosity of the pre-cast is likely to be the cause of the embedded reinforcement corroding, resulting in further fracturing and potential loss of masonry.

It is Recommend investigating alternative cladding for replacement of all existing pre-cast to de-risk the facades and provide a long-term economic solution with added benefit of the potential to include insulating properties.



We trust this meets your requirements, but should you wish for any additional information or further clarification of our allowances, please do not hesitate to contact the undersigned.

Yours faithfully,

David Manktelow
Pre-construction
davidmanktelow@paye.net



Haringey Civic Centre – Cast Stone Petrographic Analysis

Results of Mortar Analysis for Sample: Pre-Cast Stone from Haringey Civic Centre, North London.

Date Analysed: 23 – 26/03/23

Methodology: Specific volumetric, titrimetric, gravimetric and microchemical techniques are used, in addition to USB and Thin Section Polarised light microscopy (PLM), in order to determine the components and characteristics of the mortar sample, as shown in the results table:

Observations: A hard (5.5 - 6 Mohs), off-white coloured, fine - medium grained cast mortar containing fine angular quartz and feldspar grains, small shiny platelets of mica and very occasional small black magnetite:



Cut side elevation of Pre-Cast Stone (length 12cm)



Top painted and weathered surface of the Stone



Haringey Civic Centre – Cast Stone Petrographic Analysis

Results Table

Components of Mortar Determined in Analysis:	Method	Results % by Mass	
Calcium Carbonate	Calcimetry/CO ₂ emission	12.6	
Magnesium Carbonate	Calcimetry/titrimetric (EDTA)	0	
Aggregate	Gravimetric	55	
Iron Oxides	Titration with K ₂ Cr ₂ O ₇	0.2	
Cementitious Compounds in cured Mortar	%S x 2.5	18.7	
Soluble Silica in cured Mortar	Titrimetric (Conversion to silicomolybdic acid)	6.7	
pH of mortar sample	pH meter/Test Strips	12	
Soluble Salts in Mortar:			
Sulphate salts (% Gypsum)	Gravimetric (Barium Chloride)	1.8	
Nitrates (anions + cations)	Test strips.	0	
Chlorides (anions + cations)	Volhard's Method / test strips.	0	
Binder Characteristics:			
Active lime (uncarbonated lime): Ca(OH) ₂	Titrimetric	4.4	
Carbonated lime in binder (degree of Carbonation)	%Ca(OH) ₂ in binder	95.6	
Aluminium Oxide in uncured Binder	Gravimetric (Oxine)	5.5	
Cementation Index for Binder: CI	Standard Formula	1.0	
Main Characteristics of the Mortar:			
% of Soluble Silica in Uncured Binder (%S)	Calculated from %S	19.7 – 20	
%CaO in uncured Binder	Calculated	63.4	
BINDER TYPE	Dependent on the % of Soluble Silica Uncured Binder	White Cement	
Mix Ratios:			
Mix Ratio (by mass) for cured mortar	Aggregate : Binder	1.2 : 1	
Mix Ratio (by volume) for uncured mortar if binder was lime putty	Aggregate : Lime Putty		
Mix Ratio (by volume) for uncured mortar if binder was HL/Cement	Aggregate : HL/Cement	0.9 : 1	



Haringey Civic Centre – Cast Stone Petrographic Analysis

Mechanical Properties of the Pre-Cast Stone:

Porosity = 10.7% by volume

Density = 2.1 g/cm³

Water absorption after 2 days immersion in cold water = 4.9% by mass

Water absorption after 5 hours immersion in boiling water (total accessible porosity) = 5.16% by mass

Saturation Coefficient = 0.95 (note: if saturation coefficient >0.8, the mortar/stone is at risk from ice/freeze-thaw action).

Compressive Strength = 15 – 16MPa (comparable to the early 7 day strength of OPC but much less than 28 day strength).

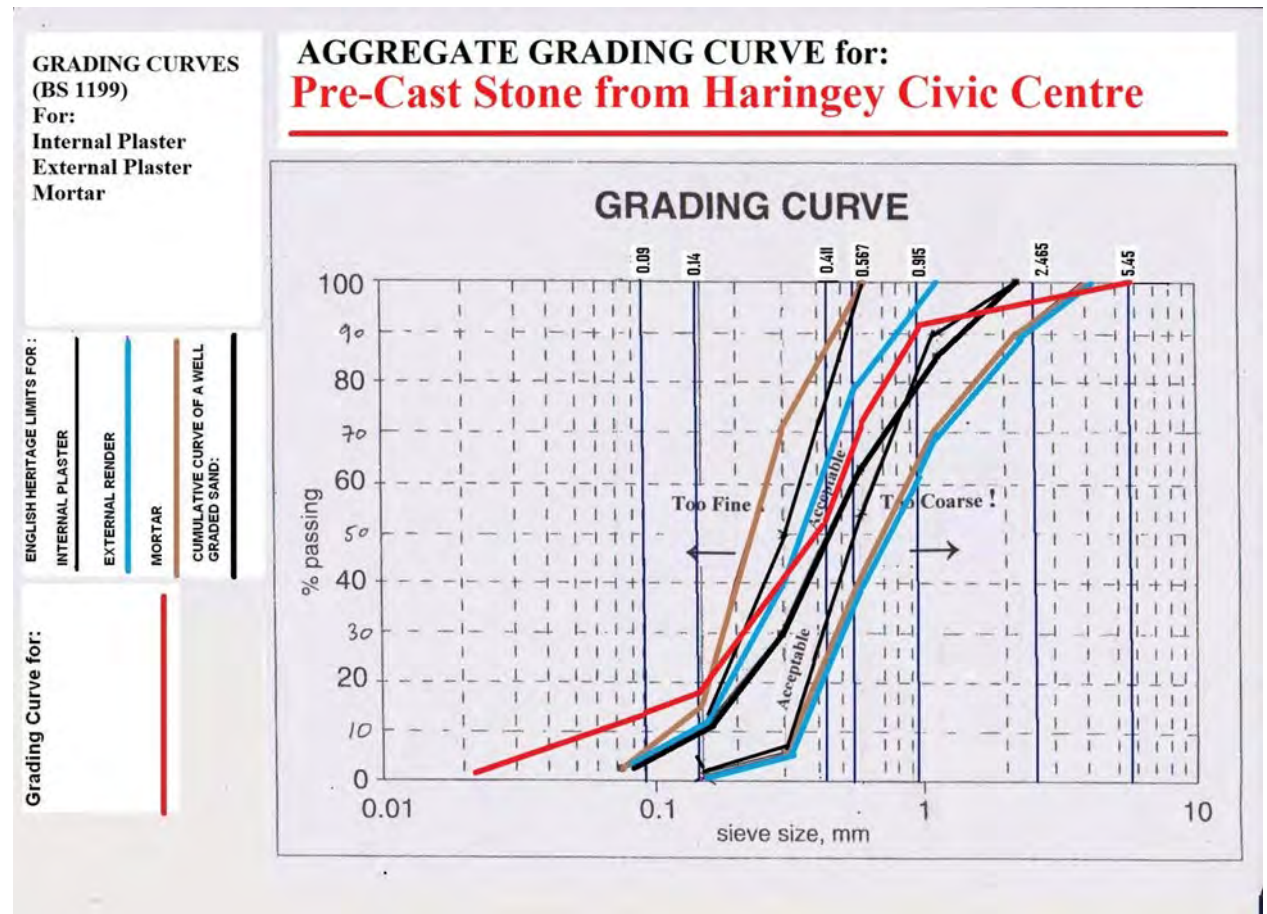
Hardness of mortar = 5.5 Mohs.

ACID INSOLUBLES: AGGREGATE MODE				
SIEVE SIZE (mm)	% RETAINED	% PASSING	% PASSING for a Well Graded Sand	CHARACTERISTICS of AGGREGATE
5.45	0	100	100	
2.465	0	100	100	
0.915	8.69	91.30	80	Angular milky/white/clear quartz grains + white orthoclase feldspar (some pinkish-white) + muscovite mica
0.567	19.56	71.73	60	As above
0.411	19.56	52.17	50	As above
0.14	33.69	18.47	10	As above + very occasional black magnetic iron oxides (magnetite)
0.09	5.43	13.04	5	As above
<0.09	13.04	0		As above



Haringey Civic Centre – Cast Stone Petrographic Analysis

The grading curve for the aggregate, shows that the aggregate is well graded and is essentially suitable for a Pre-Cast stone of medium grain texture.





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Summary of results - The Acid Insoluble Aggregate:

Is a white - off-white coloured, quite well graded, sharp, fine to medium grained siliceous material with the characteristics of a crushed white granite, composed mainly of whitish-grey orthoclase (some pinkish-white), milky-white and clear quartz grains together with a smaller amount of shiny mica platelets (mostly clear muscovite).

There are also some greyish-brown mica platelets and very occasionally some black iron oxides (magnetite):

The Binder: is equivalent to a White Portland Cement, given its **19.7 – 20%** soluble silica content.

The Mortar: has a mix ratio by volume of: **0.9 – 1 : 1** aggregate : binder



Aggregate mag. x 10



Aggregate mag. x 60. Note pinkish-white orthoclase feldspar and platelets of clear muscovite mica.



Haringey Civic Centre – Cast Stone Petrographic Analysis



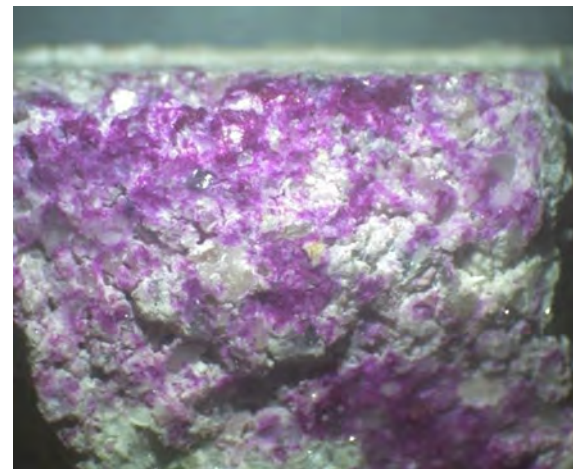
Top surface of Pre-cast stone, mag. x 60.



Surface of cast stone core, mag x 10.



Core surface mag. x 60.



Section of cast stone with Phenolphthalein, mag. x 10.
Top surface shows no purple-red colour change



Haringey Civic Centre – Cast Stone Petrographic Analysis

TOP: Section of 'stone' with Phenolphthalein, mag. x 10.

BOTTOM: whole core section with phenolphthalein (purple-red colour indicates alkaline non carbonated lime $\text{Ca}(\text{OH})_2$)

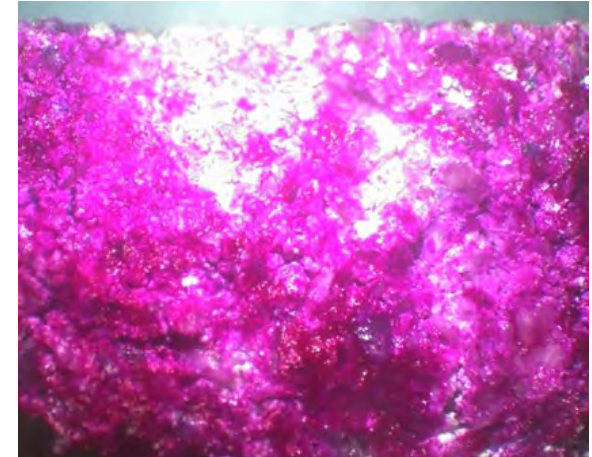
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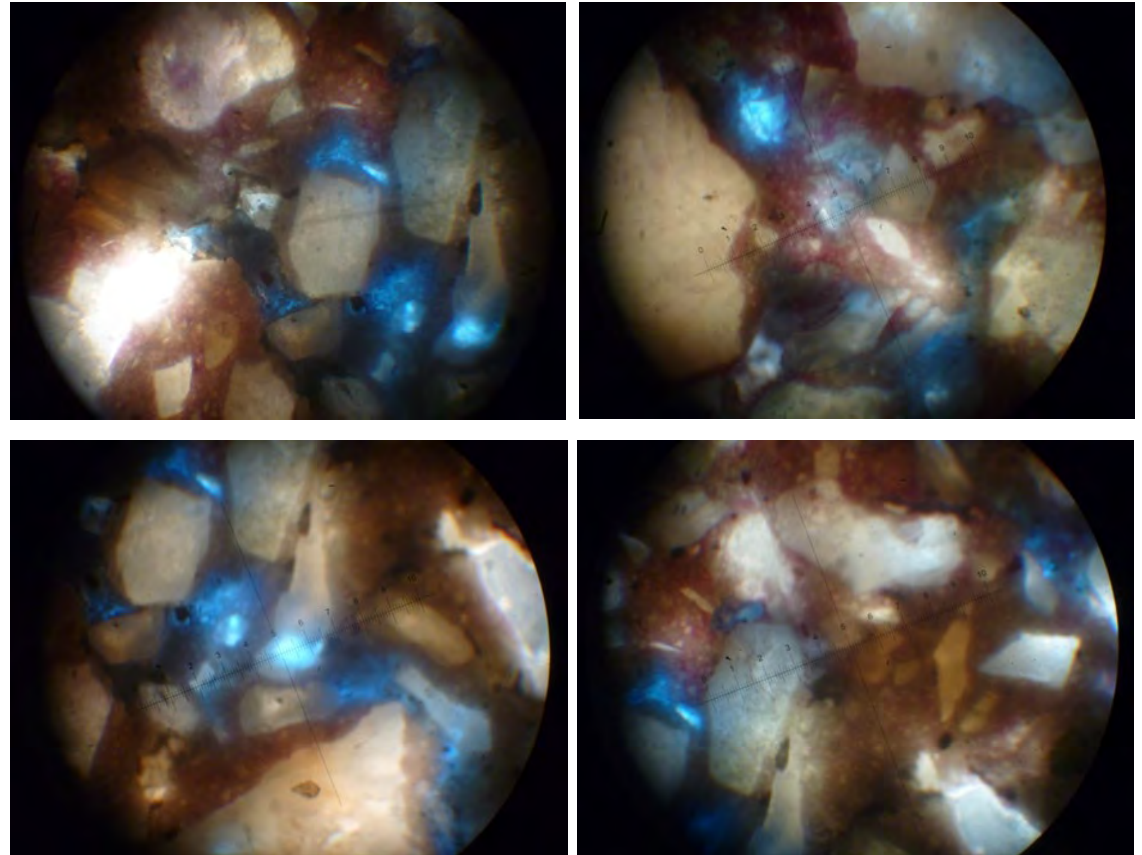
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The photomicrographs of thin sections of the cast stone (observed between crossed nicols of a PLM at a magnification of x 50, demonstrate that open and fractured pores have indeed formed to some extent in the material:

Note: blue coloured areas are open pores and micro-cracks.

Grey grains are mostly alkali feldspar and light grey–white/clear grains are mostly milky or clear quartz.

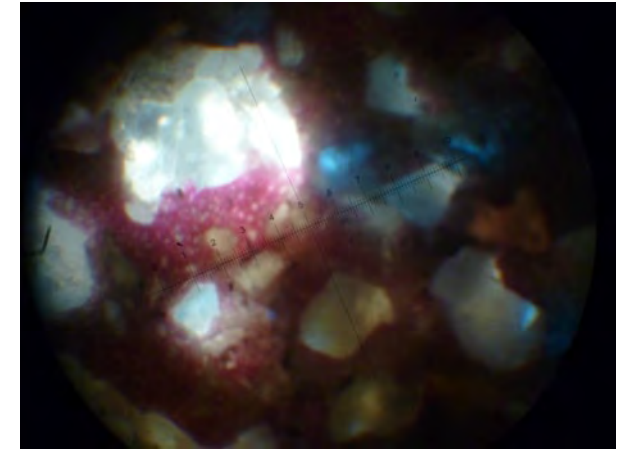
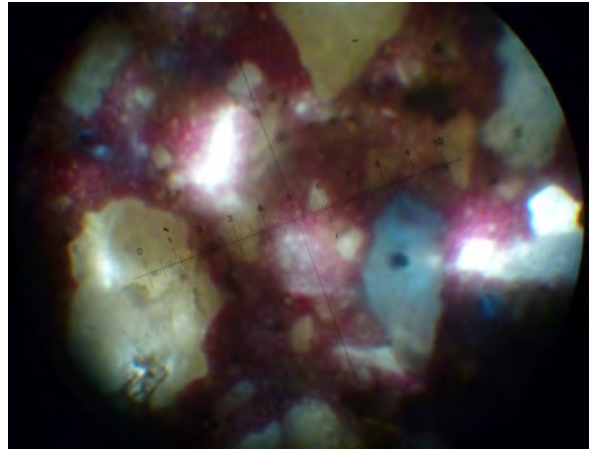
Brown areas are the cement matrix, containing much finer grains of 'powdered' aggregate.





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Note: in the following photomicrographs purple-red areas indicate cement matrix not fully carbonated:



Note: muscovite mica platelet at bottom-right showing characteristic bright high order birefringence colours.

Note: Carlsbad twinning of orthoclase feldspar at Bottom left

