Abstract Oscarshall was built between 1847 and 1853. It was the first Norwegian building to utilise Portland cement as a rendering material. The building had problems from its inception. Over the next 150 years it was continually repaired and redesigned to try to overcome its failings: internally it was damp and mouldy, externally it was cracked and leaking. The structure was thoroughly investigated using historical documents, scientific material analysis and a complete building analysis. Importantly the re-emergence of the knowledge of natural cements across Europe could be utilised to finally address the problematic render. The exterior was restored over three years allowing the understanding of the practical working methods and realistic solutions to the problems of restoring an old Portland cement facade.

1 The project at Oscarshall

1.1 The legal framework

Oscarshall is listed with Norwegian Cultural Heritage. Today it is the property of the Norwegian State and is placed at the disposal of the King. The administration is shared by the Royal Court and Statsbygg (Norwegian Construction and Property Management). The current restoration (2005-2009) included all aspects of the building, interior and exterior, as well as the grounds.

This paper refers only to the exterior work on the facade (2006-2009) of the main building.
1.2 The building of Oscarshall

Oscarshall, completed in 1852, was commissioned as a summer palace by King Oscar I and Queen Joséphine. It was designed by the Danish architect J. H. Nebelong (1817-71), who on a previous visit to Germany, became exposed to the new Romantic style as well as to new materials and technologies [1]. These were represented at Oscarshall in both the design and the materials. Traditionally built of brick and lime mortar, the render was specified to be Portland cement (PC) [2]. Nebelong must have believed that the cement’s low hygroscopicity could prevent water coming in; a belief that very quickly proved incorrect.

Further more there are indications in the archives and on the walls that PC was not proving an easy material to work with [3, 4]. Imperfectly smoothed render can be seen as well as ongoing repairs performed whilst the building was still under construction (the PC binder matches but the colour varies). This situation was not helped when the Royal Bursar managed to take control of the project [5]. He ordered the use of a cheaper and lower quality PC and forced the work to continue into winter to reduce the cost [6]. Consequently deep cracks appeared in the render as a result of poor application, low quality materials and failure due to the harsh weather and exposed position of Oscarshall.

![Fig. 1 Several different old cements with variable colours](image)

After only one winter the first set of problems appeared [5], whilst there is no record of what or where the problems were, it resulted in the ordering of more PC, sand, bricks and decorative casts. Tellingly though, there were wooden roofs placed over all the terraces and balconies each winter [7].

1.2.1 Continuous problems

From here on there were continual problems with Oscarshall. In 1863, after only 10 years, it was considered too damp and unhealthy to live in. In 1873,
fungus, ascribed to a lack of ventilation, was discovered in the floors. The Royal Chamberlain, Holst, was annually awarded large amounts of money for Oscarshall from the Royal Exchequer, until his death in 1894. By 1908 the building was closed as render and masonry started to fall from the tower [5].

1.2.2 Previous repair

Repairs were carried out regularly over its 150 year history. These repairs included; filling cracks in the cement render (using whichever mortar was popular at the time) to try and stop the ingress of water, removal of fungus and infected wood, installing ventilation into the interior (there was none in the original design), replacement of failed render areas with lime/cement mortars and the permanent closure and roofing over the roof terraces. A central heating system was installed and used during 1910 - 1940.

There are limited records of what or where repairs were made and when but we know work was done in 1927-1928, 1952 and again in 1990-1992 [5]. At some point, rather than removing spalled bricks, the damage was hacked back, nails were driven in and 10-12 cm of mortar was laid on top. Other repairs were done without even removing the paint. A major repair in 1990 included chemical cleaning, stucco and render replacement and the impregnation of walls with a silicone resin before being painted with modern acryl dispersion paint (Drywall from Scanwall). It was believed that the humidity resulted from the cracks in the render, and as a solution the render was impregnated and all cracks were filled with a modern hydrophobic paint and filler.

In conclusion it seems that the majority of problems result from:

• the original design and usage of roof terraces and balconies without adequate drainage
• the lack of internal atmospheric control
• the poor quality brick and PC usage
• sporadic use and repair of the building

Fig. 2 The lime/cement repair seen on the left side and the original grey cement seen on the right.
1.2.3 Discussions

The cause of deterioration and how it could be solved has been much discussed. It has been questioned whether the PC render and the cement casts were the original or not [5]. It was feared that overall, PC is not compatible with the extreme Norwegian climate and the building’s design (especially the roof terraces). It was therefore suggested that it would be safer to replace everything with a hydraulic lime prior to being protected with a layer of pure silicate paint. There was also some discussion as to where the damp came from; was it from rising damp originating from the ground, leaks or condensation?

1.3 The most recent restoration project

As a part of the current restoration, in 2006, a geo-membrane was installed all around the buildings to eliminate any penetration of groundwater. The pre-examinations included logging of the humidity in the walls, inspecting areas of fungus and recording the position and condition of iron beams and metal reinforcement. Finally 23 samples of render were taken to determine its actual composition.

1.3.1 The material analysis

The manufactured bricks (which were possibly local in origin) were laid in a traditional lime mortar with a good bond forming between the bricks and the old cement render. The thin section analysis proved that the original render from 1849 is PC but that there were also a few casts of Roman cement (RC) with a fine coat of PC. RC is a type of hydraulic lime burnt at a lower temperature than PC prior to being slaked [8]. Natural cement (NC) is a word used for early PC. The RC was, in the thin section-analysis was characterised by the lack of well crystallized phases of the cement clinker minerals (seen in PC) and its brownish colour, which originated from clay and iron compounds found within the impure limestone used for the lime burning. The cement clinker mineral, alite (C₃S), was absent because of the relatively low burning temperature used. Instead lumps and particles of slaked lime and unburned limestone were frequent.

The original casts were basically pure cement without any added aggregates, unlike the repairs [9]. The cement had all the characteristics of the primitive early cements; large, inhomogeneous cement grains with a grain size up to 1 mm, large well crystallized phases of belite (C₂S) and alite (C₃S), a relative low content of ferrite (C₄AF) and a high free lime content, seen as spherical hollows in cement grains. The large cement grains did not need as much sand so the mortar was relatively binder rich and had a very low capillary porosity originating from the very low water/cement ratio of the mortar used. The high cement content was responsible for the very high strength of the PC mortar. The colour varied from grey/brown to warmer grey/yellow and grey/pink.
There were 5-13 layers of paint. First lime paint, then oil paint and finally the three coats of modern acrylic paint with filler. Thankfully the silicone impregnation had not penetrated into the dense cement and could be removed with mechanical air-abrasive cleaning.

1.3.2 The cleaning

The cleaning was done with a combination of chemicals and air-abrasion systems. Torbo air-abrasion with quartz for the flat walls and JOS air-abrasion with calcite for the more delicate stucco work. The stucco work was first cleaned with chemicals to remove the organic paints and the JOS system used to remove the original lime paint.

1.3.3 The mapping and Physical Investigation

As soon as the walls were cleaned the mapping of materials and damage could start. The repair materials range from: hard, dark and grey to soft, light and white, often done without clearing off the old paint or addressing any underlying problems. The cleaned facade was mapped out by visual inspection, scientific analysis of removed sections and physical investigation using a hammer to sound walls and open up specific spots. This process also allowed for better forecasting of the extent of repair.

Fig. 3 All render above the 2nd floor and parts of the tower was probably exchanged in 1909-1913. Large parts of the corbel table had recently been exchanged with copies made of gypsum. The mapping is based on a visual investigation without analyses of the different repair mortars.
1.3.4 The extent of damage

Generally the PC and the RC has patterns of characteristic thin cracks which are traditionally thought not to be deep enough to allow in water [10]. Patterns of old cracks that had probably been repaired during the building process with old cements of slightly different colour, were also seen. In the very exposed area of the tower, systems of cracks probably due to movement, can be seen. Traditional weak spots such as the top of the arches and over openings also show cracks which are normally attributed to building movement and/or thermal movement; these are naturally worse on the most exposed walls.

All the fials (small towers) stand above the roofline and so are very exposed and badly damaged. The balconies have been repeatedly damaged by water penetration, as had the roof terraces prior to their covering. The corbel table on the main building had to have large parts completely replaced. This is logical as this corresponds with the floor level of the earlier open terrace. The same pattern can be seen at the top of the tower. This damage carries through into the interior of the building with obvious results.

There is little sign of salt damage to the brick core but massive areas of spalling behind and below damaged or cracked render do occur.

![Fig. 4 The damage on the bricks underneath the open walkway in the tower](image)

1.3.5 The methods used on flat walls

There was strong resistance to the idea of covering the walls completely with concrete because of the risk of the same problems reoccurring. Whilst some of these problems are hoped to be minimized through the use of internal climate control, the resistance to complete cover has resulted in the use of Natural Hydraulic Lime (NHL) where the render was replaced. In total the facade is about
1700 m². All bad render was removed: totalling about 50% of the wall area. The original flat areas considered sound were kept; the cleared off areas were backed with NHL 5 and finished with NHL 3.5. 5 tonnes of splatter coat and 25 tonnes of backing coat (equal to about 725 m²) have been used in addition to the 10 tonnes of mortar used to replace over 5500 bricks.

1.3.6 The methods used for the decorations

The decorative areas, being much smaller, meant there was less resistance to using NC in the backing, run moldings and the casts. Here practical tests were carried out on two different mortars; one RC from Krakow in Poland and one PC, Prompt Natural Cement (PNC) from Vicat in Grenoble, France [11]. There was no advantage found between the two except that Vicat were able to provide more guidance, a documentable history of use and all European certifications.

The original casts were removed if considered dangerous. If the casts were sitting well but heavily damaged, any old repairs were cut away and refilled in-situ. Run moldings were treated in a similar way with non-adhesive areas cut back to brick (and beyond) and re-run from brick. Any badly damaged but sound areas were again cleared of old repairs (many with layer after layer of repair) and retouched using PNC. These in-situ repairs were done on occasion onto old, very hard repair cements. This was felt to be acceptable as the PNC would adhere as easily to the newer repair as the original PC.

The aggregates used for the run moldings were 0-0.5 mm and the mix used was 1:1. The finish at the run-mouldings was pure PNC without any aggregates. Depending on the temperature, citric acid was used as a retarder. PNC requires specific handling [12], and is easy to test prior to mixing to minimize failure; it is hygroscopic so it is essential to keep the cement in sealed plastic containers on the scaffold and the short initial curing demands a controlled regime when running long sequences. The layers were thrown on wet on wet and required constant watering. The surface will discolour from the iron content during the curing, however this can be corrected by using a surface coat of paint. The PNC was used both for the splatter coat, the backing, and the finish.

1.4 Problems during the work

The main challenge came later in the project once the winter set in. In the autumn the current and recent work started to show unusual amounts of early cracking which needed investigation. Concerns regarding the range of temperatures across the area were already being raised. It was a south facing wall yet winter was drawing on and nighttime temperatures were dropping dangerously. Work was temporarily stopped as the temperature reached freezing and a delay occurred prior to the installation of a heating system: such a system is a Norwegian phenomenon which involves the complete covering of the scaffolding and the introduction of hot air blowers to increase the general
temperature to over 5°C. The heating system proved more a hindrance than a benefit as although the temperature remained relatively constant, the humidity varied dramatically, causing serious concerns about the curing of the work; when the heating failed for any reason, the prevailing temperature dropped to -20°C causing the freezing of the young render. This continued to be a problem for the remainder of the project.

Another problem was ghosting, caused by the difference in hygroscopicity between the mortars. This was and still is, highly visible after rain. Solution of this problem could either come from within the application of the fine coat or the paint systems over it.

Fig. 5 The challenge is to hide the "ghosts". Here trying out different finishes.

1.5 The final result

Fig. 6 Detail of the finished result
Overall Natural Cement was successfully introduced into a high profile restoration project in Norway. It has been proved to the Norwegian state bodies that NC is a viable product. The issues that still need to be addressed are; the problem of adhesion of a new fine coat over an old cement render, and how to mask the transfer from the old to the new mortars, often seen through the limewash with changing humidity (“ghosting”).

It is too early to give a final conclusion but the repair has survived the first very cold winter without visible damage. It is hoped that having also eliminated other likely sources of humidity in the construction, that Oscarshall will remain stable.

Notably work is currently being undertaken in Bergen on another building by the same architect using similar original materials, however this building shows far less damage; this is probably due to the buildings continuous usage over its whole life and a less demanding building style that does not use roof terraces or balconies.

2 References

2. Riksarkivet, PA 40, parcel 0169/401, 14.5.1849
3. Riksarkivet, PA 40, parcel 0173/1073, 14.5.1849
4. Slottsforvaltningen, brev fra Wedel Jarlsberg til Nebelong. 7.6.1851
6. Slottsforvaltningen, brev fra Carl Trotter til Wedel Jarlsberg. 4.4.1851
7. Riksarkivet, PA 40, parcel 0174/066, 5.11.1853