Dean and Chapter of Canterbury

The South Oculus Window of Canterbury Cathedral

The preservation of a unique medieval work of art and engineering

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6/28/2011

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1. Introduction

Canterbury Cathedral is beginning the conservation of one of its largest, earliest, and most important windows, the South Oculus window at the highest level of the south-east transept (frontispiece).

2. Significance

In the 12th century church builders were pushing the boundaries of architecture and art for the glorification of God. Light and colour were predominant in their minds, fired by the theological thought of such figures as Abbé Suger of St Denis and St Anselm, Archbishop of Canterbury.

These avant-garde builders used the most expensive building materials of the time – glass and iron – to provide huge expanses of coloured light in enormous masonry free areas filled with sumptuous stained glass, which was supported only by iron armatures (the 'ferramenta).

The 12th century South Oculus Window is one of a pair of 'oculus' window in Canterbury Cathedral – its sister is the North Oculus, located directly opposite it in the building. The latin word 'oculus' means eye, and these two eyes of the cathedral not only look into and out of the building, but also look into past, present and future through the type and antitype subjects in their iconography.

Fig.1: The exterior medieval 'space frame' on the South Oculus window

The South Oculus is an extremely rare example of a circular window with ferramenta. The absence of any stonework within the opening distinguishes an oculus from the much more common 'rose' windows of the middle ages. The combination of early date, large scale (4.47m Ø) and elaborate design of the original ferramenta makes the Canterbury pair unique.

Their complex iconography and relationship with other places and works of art in the Cathedral form a highly sophisticated and rare illustration of medieval scholastic thought.

The South Oculus Window also represents an exceptionally important example of a medieval work of art combined with sophisticated medieval engineering. The metalwork supporting the stained glass forms a medieval space frame construction, making this by far the earliest and largest known surviving example of such an engineering solution in Europe (fig.1). An identical space frame existed on the North Oculus, but does not survive.

With the exception of some very small repairs, all parts of the metalwork in the South Oculus window appear to date to its construction in ca. 1180.

2.1. History

The oculi are set into opposite ends of the eastern transepts and were glazed with representations of the Old Testament (North Oculus fig.2) and the New Testament (South Oculus, fig.3).

Fig. 2: North Oculus Window

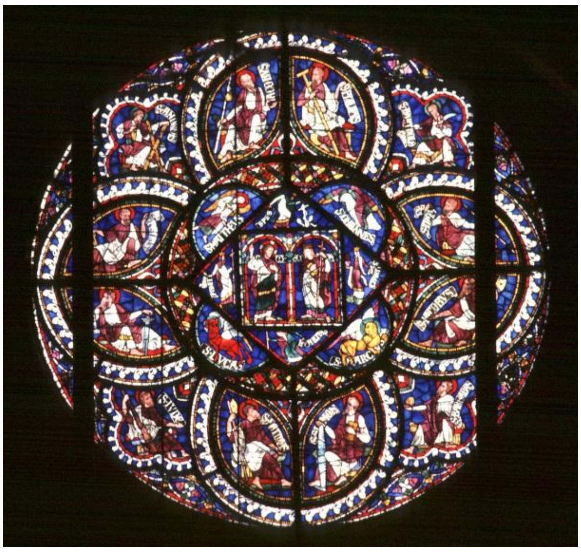


Fig. 3: South Oculus Window

In the South Oculus, fourteen original ornamental panels survive (fig.4); the remainder is a convincing reconstruction of the iconographic scheme by the younger George Austin, based on the remaining glass in the opposite window (fig.5).

George Austin Jr. was the cathedral glazier from 1848 – 62. During this time he restored a great number of medieval windows in the cathedral. His intimate knowledge of the medieval glass enabled him to produce very convincing reproductions of lost or relocated glass. He also supplied new windows in the medieval style, as well as new windows in his own neo-gothic style.

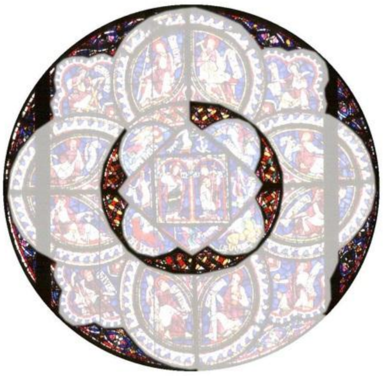
Sadly, having been considered ‘only’ Victorian glass and as such not worthy of preservation, none of Austin’s work in the Cathedral was removed for storage during the war years, and the majority of his work was lost in the Canterbury Blitz of 1942. Thankfully, the stained glass panels in the South Oculus survived.

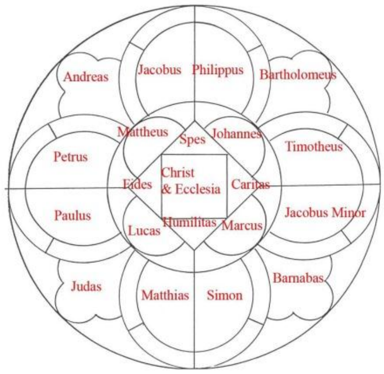
2.2. Iconography

The South Oculus cannot be understood as an isolated work of art. Rather, it is part of a complex programme of iconography that extends far beyond the window itself and at the same time firmly anchors it in its place within the building.

First, it has to be understood as a counterpart to the North Oculus. The subject of the two windows is the Old and the New Covenant, with the Old Covenant on the north side of the building, associated with the past, and with darkness. The New Covenant is shown on the south side, the side of light and of Salvation.

The figurative subjects are set into a geometric framework that in itself carries meaning: it is a finely balanced design based upon the relationship between circle and square, between the divine and the profane, eternal and temporal, God and Man.





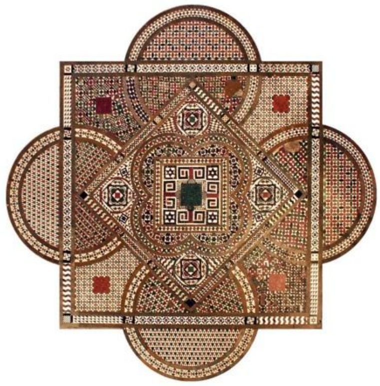


Fig.4: medieval glass **Fig.5: iconographic programme** **Fig.6: Cosmati Pavement**

A similar, but subtly different geometric design was used to create the Cosmati pavement in the Trinity Chapel of Canterbury Cathedral (Fig.6), which is also of a very similar size (5m Ø).

The two oculi together with the Cosmati pavement form a triangle at the heart of the cathedral's geometry, with the high altar at its centre and the shrine of Thomas Becket at its apex (Fig.7). In this way, the South Oculus is part of a rare survival of medieval scholastic thought expressed in colour, light and divine geometry.

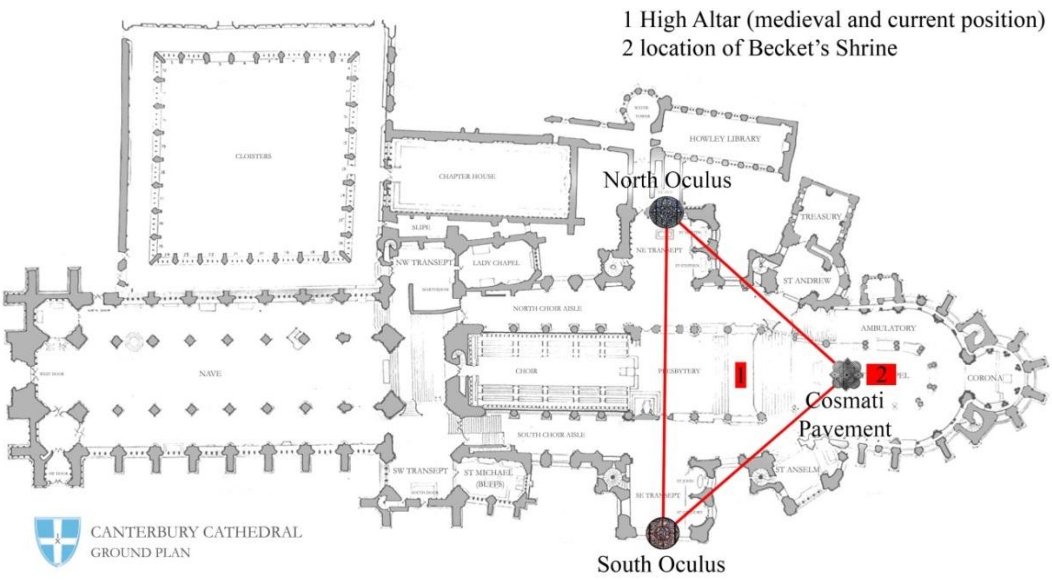


Fig.7: relative location of the Oculus Windows, the Cosmati pavement, High Altar and Becket's Shrine.

3. Position in the Cathedral

The South Oculus window is situated at 22 meters above ground level (centre of window). It was designed to be viewed at this height and from a distance. It is normally fully visible to the public both from the outside and from the inside of the building, forming an integral part of the architecture and medieval imagery of the cathedral. The window is currently scaffolded internally and externally.

On the interior, a narrow walkway at clerestory level reaches the bottom of the window. Physical access to the window is only possible from this walkway and from internal / external scaffolding. The window is therefore only accessible to trained members of the cathedral staff, as this constitutes working at height. For the duration of the conservation process it is possible to visit the site under supervision by cathedral staff; however, given the cramped conditions this is only practical for small specialist groups or individuals involved in conservation research / training and as an opportunity for donors to see the work that is being carried out.

Once scaffolding and guard rails are struck after the conservation is completed, access to the window will only be possible to trained cathedral staff and to accompanied specialist operatives (e.g. to carry out continued environmental monitoring) from the walkway on the inside at the bottom of the window.

4. Risk of Degeneration

The physical elements which make up the South Oculus window consist of glass, painted decoration, lead, iron frame, and surrounding stonework. All of them are at risk of degeneration, and all of them already exhibit damages - in case of the medieval glass and paint, very serious damages.

4.1. Stained Glass

The medieval glass surfaces both internally and externally have suffered extensive and extremely damaging corrosion. Deep craters pit the surfaces, and many glass pieces have lost most of their thickness (Fig.8). All medieval glass is affected in this way. There are multiple fractures, and the painted decoration is in all stages of lost, loose, flaking and still adhering (Fig.9). The Victorian glass, too, shows deterioration: the glass surfaces are still intact, but the painted decoration is fragile and is beginning to

Fig.8: Corrosion damage – 'pitting'

Fig.9: Corrosion damage – paint loss


Fig.10: Medieval glass showing corrosion damage

show damages. All panels are distorted and leak heavily, which is impacting the stonework surrounding the window (Fig.11).


Fig.11: Water damage to stone cill

4.1.1. Chemical deterioration processes

The main factor in the corrosion of glass and glass paint is liquid water. Medieval glass is particularly vulnerable to water damage, as some of the components used in its manufacture make it less durable than modern glass. Atmospheric gases, pollution and micro-organisms all contribute to the deterioration, but without the presence of liquid water these deterioration processes are slowed down significantly.

The exchange of alkali ions from the glass with hydrogen ions from water results in a leaching process that erodes the glass surfaces. Thinning and cratering of the glass can eventually lead to the complete loss of the material. A secondary reaction between the leached alkali ions and atmospheric gases results in salt deposits on the glass surfaces. These deposits attract and hold moisture on the glass and thus supply more corrosive agent; repeated drying and wetting cycles cause micro-cracks both in the glass surface and in the painted decoration.

Damp and corroded glass surfaces provide excellent opportunities for colonisation by micro-organisms. These have been shown to further damage the glass both through chemical (excretions) and mechanical (growth pressure) processes.

4.1.2. Mechanical deterioration processes

The South Oculus, at 22 meters above ground and facing due south is fully exposed to high wind loads, rain, hail stones, as well as significant fluctuations in temperature.

On a macro level, all these factors cause the distortion of the lead matrix which holds the stained glass panels together. This can result in glass fractures and in the loss of adhesion of the panels to the supporting iron framework.

On a micro level, temperature fluctuations cause the deterioration of glass surfaces, promote flaking off of painted decoration, and drive rapid drying and wetting cycles which accelerate corrosion processes.

4.2. Metal frame

The general condition of the metal framework is good and appears stable and currently able to cope with the forces acting upon it. However the fact that the North Oculus external grille has been lost demonstrates that there is a potential for failure on the South Oculus. The ferramenta and frame have remnants of a painted surface which in the main has failed and is now on the grille flaking and peeling from the surface. There is a coating of corrosion products on the surface of the iron and under the flaking paint, however the rust streaking/staining to the stone appears to be light considering the amount of iron surface exposed.

Necking has occurred to the tie bars/pins which connect the external grille with the ferramenta. This corrosion is caused by an electrochemical reaction between the wrought iron pins/bars and the wrought iron ferramenta. It is possible that this is a fairly recent (in the life span of the South Oculus window) development; close inspection of this area showed that the joints were filled with a white filler which is probably window putty and as the linseed oil has evaporated it has left the chalky filler which is absorbing and holding moisture - an essential ingredient for the promoting of corrosion.

There are a number of old repairs and breaks to the grille and ferramenta, but they do not affect the overall stability of the structure.

4.3. Stonework

Rust stains cover the lower portion of the cill. The amount of staining is, however, very little considering the amount of exposed ironwork above it. There are no plans for cleaning the rust stain. The ironwork frame is held into the surrounding stonework at 16 anchor points. There is visible stone damage at some of the anchor points, the main area being at the 3 o'clock position - this is from rust jacking of the iron fixings promoted by water ingress to the stone through failed pointing and joints.

The primary fixing at 3 o'clock is achieved by extending the main ferramenta bar into the stone work which would have been mortised to take the ironwork. Water ingress through failed pointing has caused this fixing to corrode and ultimately through corrosion jacking has burst the stone. There are other areas around the South Oculus window which correspond to fixing points that show signs of either repaired / replaced stone possibly carried out in the 1920's, or more recent cracks and fractures.

5. Project Description

The aim of the conservation project is to preserve this unique and important work of art in its entirety and in the location it was created for, and to reduce the rate of further deterioration to an absolute minimum.

5.1. Protection

The advanced rate of corrosion of the medieval glass, together with signs of beginning decay on the Victorian panels, make it imperative that the South Oculus glass receives environmental protection.

To date, the most effective method of achieving this is the installation of a well-designed protective glazing system. The North Oculus window was set into such a system in 1992, and this serves as a template for the protection of the South Oculus window. This glazing system will also provide additional structural support to the iron framework, reducing the loads it currently has to withstand.

5.2. Environmental Sensor Study

In 2007 and 2008 a study was carried out over a period of 18 months by environmental monitoring specialists TC Associates Ltd. to evaluate the effectiveness of the existing protective glazing system on the North Oculus, and to investigate if the system will work well for the South Oculus. A sample section of the South Oculus window (fig.12) was removed from the original frame and set into a temporary sub-frame behind protective glazing. A wide range of data was collected over an eighteen month period. The results were then compared with data taken from the equivalent unprotected section of the same window.

Fig.12: Data collection on test section

The data collected included humidity, temperature, air flow rates in the interspace between the protective and the historic glazing, as well as general weather data collected from a weather station mounted on the external grille of the window.

5.3. Photogrammetry

In addition to the collection of environmental data, a program of photogrammetry measured the spatial behaviour of the largest panels in the protected and unprotected sections.

Photographs were taken at two-monthly intervals. The accuracy of the measurements was +- 0.3mm.

5.4. Test Results

The environmental monitoring programme revealed that – for the small sample section - the proposed protective glazing system produced the desired positive effect compared to the unprotected section. Some aspects of it perform even better than in the existing protective glazing system on the North Oculus, which itself was shown to work very well indeed.

No condensation was measured on the protected historic glass, while the unprotected stained glass was regularly dripping with water on the internal as well as the external face (there obviously from rain water).

At no time did the protected glass reach higher surface temperatures than the unprotected glass. During cold periods, the surface temperature of the unprotected glass dropped far more than that of the unprotected glass.

This means that the amplitude of temperature difference is significantly reduced through well ventilated protective glazing, reducing thermal stress on historic glass and lead.

Liquid water on the historic glass is now completely absent, and since water is the primary agent of corrosion of glass, the elimination of water on its surface will vastly reduce the rate of corrosion.

5.5. Structural Analysis

The University of Minho, Portugal, has carried out a research project into understanding the structural capabilities of the original window, and in particular trying to establish the function that the external grille plays in this. They have undertaken dynamic identification by fixing temporarily accelerometers to the frame and then testing the structures response to minor physical interventions such as tapping with a rubber hammer. Based upon the data collected on site the ironwork will be modelled and a finite element analysis undertaken to allow a better understanding of the structural performance under a number of different load cases.

The final results of the study are expected in the first half of 2012, but early indications are that the structure is immensely strong and still performs exceedingly well.

6. The Conservation Effort

The stained glass will be removed from the medieval ferramenta and replaced there with colourless leaded lights made from modern 'Float' glass, kiln distorted and treated to reduce reflexion. An exact replica of the medieval ferramenta frame will be manufactured by a local traditional blacksmith to hold the historic glass.

This new frame will be set on the internal face of the stone reveal, and will provide the setting for the historic stained glass. The two ferramenta frames will be linked as described above (point 2.2.), creating an interspace with ventilation gaps to the interior of the building. This will provide air movement between the two layers of glass, giving the historic stained glass a far less challenging environment and thus significantly prolonging its life as well as the life of any conservation materials used in repairs.

The historic glass will be treated by the Cathedral's own stained glass conservation team in a minimum intervention approach: careful light mechanical cleaning concurrent with localised paint and fracture consolidation. No re-leading or replacement of glass will be undertaken. As much as possible, all interventions will be reversible. A full photographic, diagrammatic and written record will be made and archived both in digital format and as hard copy.

The major impact on the structure of this window is wind loading, and studies confirm that it still meets its performance requirements (University of Minho study). In order to reduce interventions on this unique survival, we propose to use the new framework for the historic stained glass to give additional support to the existing ferramenta. In this way we will avoid the need for interventionist repairs to the original ironwork. The space frame will effectively be increased in depth and this in strength. The two frames will be isolated electrically to eliminate any potential electrolytic reaction between old and new metals.

The surface treatment of the medieval iron will be carried out by a specialist metal conservation firm, following successful treatment trials (fig.13). Treatment will be restricted to very gentle mechanical cleaning, followed by a wax coating with rust inhibitors (Waxoyl).

Fig.13: Cleaning and treatment trials on the metalwork

Observations have shown that paints and putties used in the past can promote corrosion. Traditional blacksmithing techniques for wrought iron are surface treatment with oils or waxes, which have been used for many centuries. They are reversible, do not promote corrosion as paints can, and have been seen to be the best preservers.

The window appears to be firmly held in place and only fixings that actually show signs of problems (visible damage to the stone) will be repaired by the Cathedral's own masonry department. The shattered stone will be replaced as it was originally, including the mortised socket. The iron will be treated using the same techniques as all the rest of the ferramenta, with an additional coat of traditional lead oxide paint to reduce the risk of corrosion re-occurring. Re-fixing will be done in the same way as the original, reusing the original wedges and sealing the fixing within mortar.

7. Timetable and Work Plan

August 2007 – October 2008: preliminary studies and recording

June-July 2011: Removal of glazing

June 2011: Commence manufacture of protective glazing.

August 2011: template for new sub-frame, blacksmith in attendance.

August – September 2011: Metal conservation.

September – December 2011: Manufacture of new sub-frame.

October 2011: Installation of protective glazing.

December 2011: Installation of sub-frame.

January – April 2012: Installation of historic glass.

June 2012: Project finish.

8. Evaluation of the Project, Criteria for Success

8.1. Evaluation through continued monitoring

It is planned to again install environmental sensors once the conservation and re-installation are complete, and to monitor the environmental condition the glazing is exposed to over an extended period of time. The data collected from the fully protected window will be compared to those collected from the test bed to verify the efficacy of the protective glazing system, and – importantly - to evaluate the validity of the test bed data. This will inform the design of future trials. It will also enable the Cathedral conservators to build up the first long-term data base of the environmental conditions of a protected window in situ.

The ironwork which is dateable will be accurately measured in ca. ten to fifteen places that are accessible from the inside by the removal of the glazing, in order that the rate of corrosion can be calculated in the future.

Reference to the monitoring is to be referred to in all Quinquennial inspections. The data will be held by the Cathedral stained glass conservation studio.

8.2. Publication

The results of the test bed trial were presented to the conservation community as part of a 2-day symposium held at Canterbury Cathedral in October 2009, entitled ‘New Techniques for Old Problems, Conservation on Canterbury Cathedral, Recent Projects and Research’.

Dr. Jane Geddes undertook research into the significance and spread of large oculus windows in medieval architecture, and into the use of space frame construction associated with them. She presented the results of her investigation at the conference of the British Archaeological Association in 2009.

Another symposium is planned at the end of the conservation project to present the findings made during the conservation of the glass and ferramenta, and the continuing environmental monitoring.

8.3. Criteria for Success

The conservation effort will be judged successful if monitoring shows that environmental stresses are significantly reduced in the real installation. The rate of continuing deterioration on the historic stained glass is expected to be below measureable levels.
For the exposed ironwork the rate of deterioration may well be measureable, however it is expected that the time scale for measureable changes will range in the decades rather than in years.