

Replacement of natural stone in conservation of historic buildings

Evaluation of replacement of natural stone at the church of Our Lady in Breda

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In this paper the decision process and the choice for specific types of natural stone for conservation purposes are investigated.¹ Two successive 20th century conservation campaigns at the church of Our Lady in Breda are analyzed. It was specifically investigated in how far the architects involved took aspects of compatibility and durability of the replacement stone into account. It is concluded that in both conservation campaigns arguments of durability and sometimes compatibility have been used. A historic line over the twentieth century interventions runs from attention to aesthetic compatibility over durability to technical compatibility.

Keywords: Conservation, restoration, compatibility, durability, natural stone, evaluation

1 Introduction

This paper reflects a part of the PhD research with the working title *Replacement of Natural Stone in the Twentieth Century in the Netherlands*. This study is part of a program in the research portfolio of the department *Modification Intervention and Transformation* (@MIT) at Delft University of Technology. Gaining knowledge of techniques for diagnosis and conservation is the general aim of this program as expressed by Van Hees [2007]. Within the program the dissemination of the knowledge gained during research projects is a major

¹ Here, the definitions of conservation, preservation, restoration and reconstruction from the Burra charter, 1999 will be used. Conservation means all the processes of looking after a place so as to retain its cultural significance. Preservation means maintaining the fabric of a place in its existing state and retarding deterioration. Restoration means returning the existing fabric of a place to a known earlier state by removing accretions or by reassembling existing components without the introduction of new material. Reconstruction means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material into the fabric.

point of attention. The ultimate goal of the program in general and this research project in particular is to contribute to the quality and durability of future interventions. The research aims to identify the decision process leading to the choice of specific types of natural stone as replacement for pre-existing (sometimes original) stone. There is specific focus on the question whether or not the restoration architects took aspects of durability and compatibility into account and if so how. The outcome of the research in several case studies is expected to result in data that will assist in future conservation campaigns where replacement of natural stone is considered. It also allows to reflect on conservation campaigns and could lead to suggestions on how to improve the decision process in replacement of natural stone in historic buildings.

The term compatibility was introduced at the Dahlem conference [Teutonico et al, 1997]. Slight modification of their definition² leads to the definition that is used in this research; see also [Van Hees et al, 2002]: Compatibility means that treatments or introduced materials will not have negative consequences for the existing historic fabric, neither in a technical, esthetical nor historical way. Those three aspects of compatibility can be subdivided into several dimensions to cover all the characteristics of the intervention. For each dimension it is necessary to establish acceptable compatibility tolerance limits to assess and compare interventions.

Reasoned replacement of natural stone in historic buildings has been common practice in conservation campaigns over the years. Many (decorative or structural) elements have been replaced, some of them more than once. Nowadays conserving historic (listed) buildings in the Netherlands means most of the time reconstruction (i.e. introduction of new material) by mortar repair or replacement of blocks of natural stone. Due to evolution of conservation philosophy, legislation, the availability of new investigation techniques, better knowledge of material properties, and a broader offer and availability of alternative stone types, conservation practice has changed slowly over the years.

This paper deals with the Church of Our Lady in Breda, one of the case studies in the PhD research. Two restoration campaigns carried out during the 20th century are analyzed and the consequences of choices are evaluated. Nineteenth century maintenance

² A treated material should have mechanical, physical and chemical compatibility with the untreated historic materials under consideration. Simply stated, compatibility means that introduced treatment materials will not have negative consequences. ... And other values like color, texture, and esthetic presentation must be considered. However, as long as there are no negative consequences which can be predicted, even "dissimilar" materials should not be ruled out.

and the restoration of the tower at the end of the nineteenth century are not analyzed due to a lack of information.

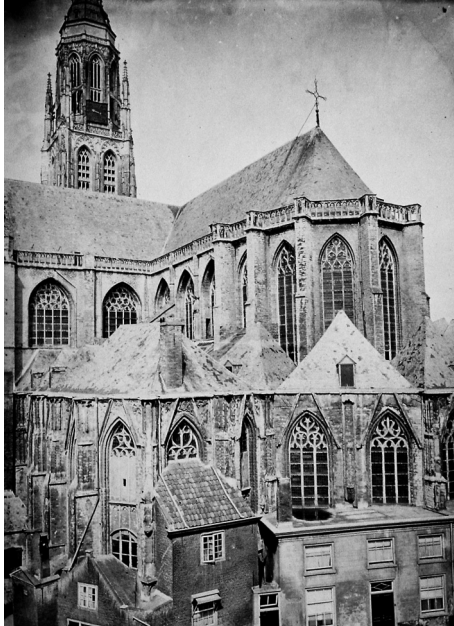


Figure 1: Church of Our Lady, 1865 (Kannemans en Zoon, Albuminedruk, Breda 1865, from Van Wezel, 2003)



Figure 2: Church of Our Lady, 1991 (postcard from the archives of the Church of Our Lady, Rolf ter Veer, Breda, 1991)

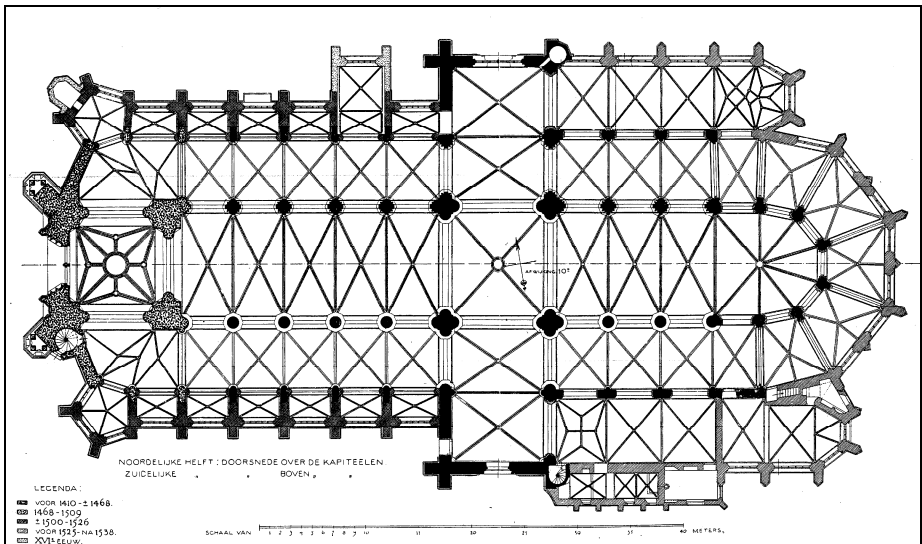


Figure 3: Ground plan of the Church of Our Lady (From: Kalf, 1912)

1.1 *Conservation history of the Church of Our Lady*

The oldest parts of the Church of Our Lady in Breda date back to the 15th century [Van Wezel, 2003]. The current state of the building is the result of two large conservation campaigns in the 20th century. The first took place from 1904 to 1969 under the guidance of successively J.J. van Nieukerken (1854-1913), his sons M.A. (1879-1963) and J. (1885-1962) van Nieukerken and later J. de Wilde³. Figure 1 and 2 illustrate the architectural changes that are the results of the first conservation campaign. Despite the developing approach with respect to conservation of historic buildings, the facades and chapels of the choir aisle have been reconstructed and completed in the spirit of Viollet-le-Duc and his Dutch followers Victor De Stuers and Pierre Cuypers [Van Nieukerken, 1933]⁴.

Because it was difficult to collect enough money, the restoration took place in several phases. In 1904 the campaign started with major work on the roof structure, the gutters and the underlying masonry. The reconstruction of the *Prinsenkapel* and the *Niervaartkapel* was part of the second phase, starting in 1910. Through successively choir aisle, transepts, choir, nave and tower the restoration campaign finished officially in 1969.

The second overall conservation campaign took place in the period 1991-1998 under the guidance of architect prof. J. van Stigt. This campaign was called a *technical restoration* by the architect himself; because it was meant to improve the (technical) quality of the building envelope to create optimal conditions for the conservation of several monuments of historical importance inside the church [Van Stigt, 2007].

1.2 *The Niervaartkapel*

Figure 4 to 7 give an overview of 100 years *Niervaartkapel* to illustrate the architectural changes that have been made during both conservation campaigns. The first work at this part of the church started in 1910 and ended in 1921. Except for some (load bearing) parts the complete Medieval façade (Lede stone) was reconstructed in French limestone (mostly Reffroy). Figure 4 illustrates the condition before reconstruction, documented by Van Nieukerken in his report from 1933:

- Rainwater entered the building and weathered the stone because the connection between the roof and the façade was leaky. Many repairs were executed during the past years with cement mortar;
- The mouldings of the canopies were almost totally eroded;

³ From 1956 onwards.

⁴ See Denslagen [1987] and Tillema [1975] for reflections on the changing conservation approach regarding the Church of Our Lady.

- The window arches and traceries were all in a bad condition. Partly because of rusting iron and partly because of water seeping through the material due to the absence of well functioning dripstone mouldings;
- The leaded glass had loosened from the traceries. Many glass sheets were broken or gone. Some of the windows were filled with brick masonry;
- The fillings of the canopies and spandrels had almost totally gone.

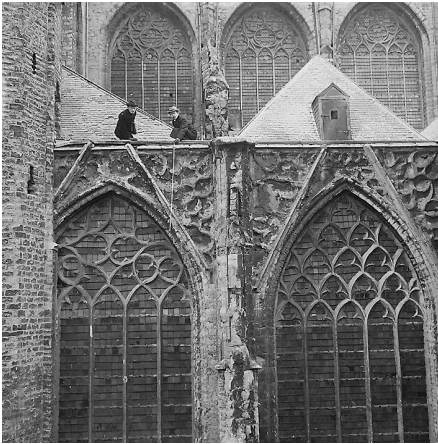


Figure 4: Niervaartkapel, 1909, before the first conservation campaign (photo: RCE)

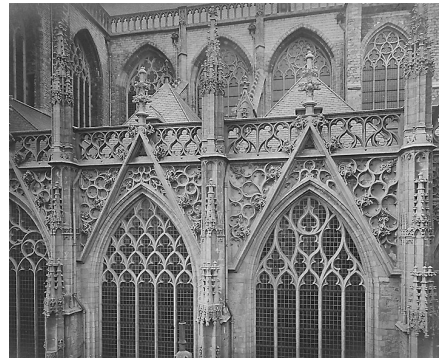


Figure 5: Niervaartkapel, 1918, shortly after the first conservation campaign (photo: RCE)

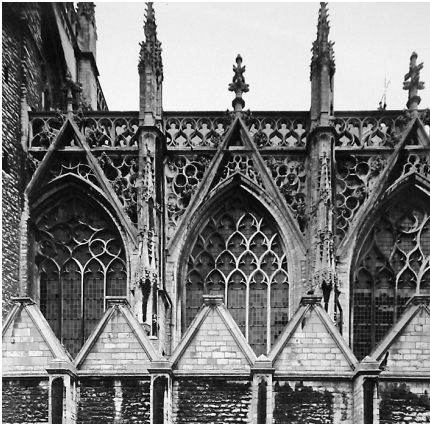


Figure 6: Niervaartkapel, 1992, before the second conservation campaign (photo: architectenburo J. van Stigt b.v.)



Figure 7: Niervaartkapel, 2006 (photo: author)

Architect Van Nieuwerkerken created a step-by-step reconstruction plan for the whole choir aisle by means of a profound study of the ornaments⁵. Based on traces of late-Mediaeval sculptural work and hypothesis on how it could have looked, the whole decoration of the chapel has been reconstructed. In relation to his way of working, the architect refers to the well known book *Histoire d'un hotel de ville et d'une cathédrale* by Viollet-le-Duc from 1879⁶.

The reconstruction of the *Niervoartkapel* gave rise to fierce discussions on the continuation of the restoration (choir aisle). The restoration architect struggled with the *modernists*, lead by Jan Kalf, managing director of the *Rijksbureau voor de Monumentenzorg*⁷, since its creation in 1918.

Figure 6 shows the south façade of the *Niervoartkapel* in 1992 after having been exposed to weathering for approx. 75-80 years. The appearance of the façade changed over the years due to the weather conditions and environmental pollution; the sculptural work was hidden behind a black fog of dirt and gypsum. Most of the pinnacles and finials had weathered in such a way that they had to be removed and replaced by copies. Figure 6 shows the 2006 situation where the upper pinnacles and finials have been renewed in Tepla trachyte. Some of the dripstone mouldings and large parts of the lower pinnacles have also been replaced by copies in Tepla trachyte during the conservation campaign of 1995-1998. Besides the replacements, repairs have been carried out in Monulit mortar⁸.

The series of photos (figure 4-7) also shows the transformation of the glazing. The 1909 situation shows crossing bars combined with saddle bars, some glass sheets are missing and repairs are clearly visible. Except for some pollution effects the 1918 and the 1992 situation are the same. Saddle bars no longer support the leaded glass and the construction of rivet and wedge has been changed. The photo from 2006 shows another image; protective glazing and nylon net against pigeons have been added in the period 1995-1998. For an in depth analysis of the glazing see Quist and Van Hees [2006] and Quist [2006].

⁵ See Van Wezel [2003] for a description of the authentic Renaissance ornaments.

⁶ A Dutch translation of this book by Th. Molkenboer with a preface of P.J.H. Cuypers was published in 1897.

⁷ National Service for Built Heritage.

⁸ Monulit is a two-component mineral repair mortar. Shortly before application the two components (one existing of zinc oxide and ground limestone and one existing of a zinc chloride solution) are mixed together.



Figure 8: Finial before placement in 1906 (photo: RCE)



Figure 9: Finial on the choir aisle, 1993 (photo: Rob van Hees)

2 Replacement of natural stone during first conservation campaign

2.1 Research in the early twentieth century

On special request of the Restoration Committee of the Church of Our Lady, architects J.J. and M.A. van Nieukerken undertook in 1904 a journey to the north of France in search for the soundness of St. Joire limestone to be used in historic monuments [Van Nieukerken, 1904]. From the reports of the committee it is not fully clear why this journey took place. The immediate reason seems to be related to the delivery of natural stone in the spring of 1904 that did not meet the desired quality standards. Before travelling to France, Van Nieukerken contacted several restoration architects to ask them for their experience in using St. Joire limestone. Among those architects were Cuypers, Nieuwenhuis, Hezenmans and Frederiks. All gave testimony of positive experience with the use of St. Joire [Van Nieukerken, 1904]. These positive references were no reason for the restoration committee to stop Van Nieukerken from personally travelling to the quarry of St. Joire and other places to study restoration and reconstruction work executed in St. Joire. Aesthetical

compatibility (i.e. the colour after some years of weathering) is what Van Nieukerken was looking for.

Durability was only referred to in terms of 'the material does not show major deterioration within 40 years'. There is no indication that the architects did any laboratory tests like chemical resistance tests, freeze tests, wear tests or pressure tests to assess (more scientifically) the quality of natural stone, although the tests were available (see for example Van der Kloes [1908]). Also microscopic analyses were not performed. Remarkably enough, Koning & Bienfait were commissioned to carry out several analyses on historic mortar, hydraulic lime and Portland cement in the period 1906-1910.

The journey taught Van Nieukerken that quarrying of St. Joire had stopped almost ten years before and that at the same time stone from the quarries of Reffroy and Givrauval was supplied, " ... *qui sont exactement de la même nature et de la même qualité que le St. Joire et qui ont toujours été vendues mélangées ensemble et tous l'un ou l'autre de mons de St. Joire, de Reffroy en de Givrauval.*" [Van Nieukerken, 1904]. Concerning the quality of the stone of Reffroy Van Nieukerken judges that it is of good quality although less hard than Euville limestone and Gobertange limestone and that it hardens when exposed to air. Most probably the quarry would be in use for the next twenty years and the stone would be available in large enough dimensions. Van Nieukerken expects the stone to colour with the old, original stone used at the Church of Our Lady in Breda.

2.2 Introduction of French limestone

Based on the earlier mentioned report the Reffroy limestone was chosen for the first and second phase of the restoration. The first delivery of limestone for the restoration of the church took place in the summer of 1905 by G.W. Sanches from Amsterdam. The limestone was extracted from the quarry of Reffroy owned by *Civet & Pommier*, transported to the depot in Namur of *Armand van Wylick* by boat and delivered in Breda by train⁹. Regarding the building specifications¹⁰ this delivery comprised 17.1 m³.

Many letters to different suppliers were sent for the delivery of sawn limestone for phase two of the restoration (i.e. restoration of the buttresses on the south side of the church). Suppliers that had been contacted were *Civet et Pommier* in Savonnières-en-

⁹ See several letters in the archives of the Church of Our Lady. SA Breda. Archief architectenkantoor J. en M.A. van Nieukerken te 's-Gravenhage, betrekking hebbend op de restauratie Grote Kerk (aanwinst 1974). Afdeling III nummer 130, inv. nr.36-38

¹⁰ SA Breda. Archief architectenkantoor J. en M.A. van Nieukerken te 's-Gravenhage, betrekking hebbend op de restauratie Grote Kerk (aanwinst 1974). Afdeling III nummer 130, inv. nr.36-38

Perthois, *Singels* in Dordrecht, *Schotel* in Dordrecht, *Beltman* in Deventer and *Petit* in Breda. Finally J.B. Petit¹¹ got the commission for the delivery of at least 20.7 m³ Reffroy. At the end of 1913 Reffroy could not be delivered anymore by *Petit* because the extraction came to an end. The search for a new stone started: St. Joire was advised by several people¹² although P.J.H. Cuypers continued to advise Reffroy¹³. Also other types of stone were proposed, like Tannois and Mézangère. While Van Nieuwerkerken doubted which stone to use instead of Reffroy, the whole political and economic situation of Europe changed with the outbreak of World War I (WW I) on July 28, 1914. When the Germans attacked Luxemburg on August 1st and France declared war on Germany on August 3rd, the Great War (WW I) entered the Western part of Europe. From that moment on it was almost impossible to do business with Belgium and France.

From the archives it looks like every piece of French limestone in the Netherlands, especially St. Joire and Reffroy, was examined in the period 1914-1919 as possible replacement stone to be used by Van Nieuwerkerken and his site foreman Vriendt¹⁴. Several small quantities of St. Joire and Reffroy were delivered to Breda by different suppliers. In the correspondence between the architect van Nieuwerkerken, Vriendt and several suppliers of natural stone many types of stone were mentioned. The following list shows the types of stone mentioned in the correspondence¹⁵:

- Morley limestone
 - Last large quantities delivered to restoration of Church of Our Lady in Dordrecht and St. John's cathedral in 's-Hertogenbosch in 1916
 - In stock (in small quantities) at several suppliers
 - Although no specific reason for rejection is mentioned, it is clear that Van Nieuwerkerken did not like this stone because of the multiple rejections. Most probably because of its white/greyish colour.
- Savonnière limestone
 - In stock at *Slinger*, Dordrecht

¹¹ Jean Baptiste Petit (1854-?); his father was a stonemason or stonecutter from Seneffe, Hainaut, Belgium: Charles Philippe Petit (1807-1897). See

<http://www.karinevanderwerf.nl/Genealogie/Kwartierstaat.htm> (visited december 2008).

¹² Including Van Valkenburg, foreman at the restoration of the Cathedral of 's-Hertogenbosch where St. Joire was in use.

¹³ Most probably he is not aware of the fact that the extraction of Reffroy is coming to an end.

¹⁴ Before working in Breda, G. Vriendt (?-1922) was site foreman at the restoration of the Lebuinuskerk in Deventer.

¹⁵ SA Breda. Archief architectenkantoor J. en M.A. van Nieuwerkerken te 's-Gravenhage, betrekking hebbend op de restauratie Grote Kerk (aanwinst 1974). Afdeling III nummer 76b, inv. nr. 5-6.

- English limestone¹⁶
 - Offered by *Natuursteenhandel W.G. Simonis*, Rotterdam
- Euville limestone
 - In stock (in small quantities) at several suppliers
 - In stock in Namur before the Great War
 - A small quantity is used in Breda
- Senonville limestone
 - In stock in Namur before the Great War
- Pouillenay limestone
 - In stock in Namur before the Great War
- Tannois limestone
 - In stock in Namur before the Great War
 - To porous and unsecure
- Vaurion limestone¹⁷
 - Offered by *Natuursteenhandel W.G. Simonis*, Rotterdam and *Beltman*, Deventer
 - Used for the Itterson hospital in Gouda
 - Colour is to yellow but most important it is to expensive to transport the stone to the Netherlands (by boat via Le Havre)
 - A small quantity is used (for test purposes) in Breda
- Brauvilliers limestone
 - Offered by *Rotterdamsche Steenhouwerij*
 - A small quantity is used in Breda
- Arzweiler sandstone
 - Reference is made to the Hirsch department store in Amsterdam
 - Van Nieukerken does not approve the colour(s)
- Weibern tuffstone
 - In use at St. John's cathedral in 's-Hertogenbosch with positive references
 - Colour is to dark to match the Reffroy
 - To porous
- Obernkirchen sandstone
 - Used for seven high windows of the choir
- Radwitz sandstone

¹⁶ Type and origin are not mentioned.

¹⁷ In later years Vaurion limestone is often called Massangis limestone

- Udelfangen sandstone
 - Does not match in colour
 - Over 10 m³ in stock at *Beltman*, Deventer
- Gildehaus sandstone

The most striking detail of the search for a suitable replacement stone is that there was no reference at all to the original stonework in Lede. When the architect was searching for a new stone the only reference mentioned is the Reffroy used in the years before. The new stone had to colour (in a short time) with the Reffroy. For this reason (among others) Vaurion limestone, Weibern tuffstone and Udelfangen sandstone were rejected although Vaurion had been used in small quantities for test purposes. In contradiction with the search for a matching colour several square meters of Obernkirchen sandstone have been used. This stone was chosen for its known durability and availability in large quantities and therefore the stonemasons could keep on working. To form a visual unity the stone was only used for the seven windows and not for single blocks in other parts of the church¹⁸.

Looking at the 1991 situation before restoration (see figure 2) and the current situation after restoration (see figure 10) it can be concluded that the Obernkirchen sandstone blends wonderfully well into the background of Lede and Gobertange stone while the stone itself does not appear to have degraded.

Cleaning of the Church of Our Lady (during the nineteen nineties) was done by means of the JOS-method, using stone powder (grains 0.005-0.3 mm) and water (30-60 l/h) at 0.5-1.5 bar. Although no chemicals were used it looks as if Fe-(hydro)-oxides were made active and transported to the surface because the stone looks more yellow after cleaning than before. The mixture of yellow and gray tones colours well with the medieval Lede stone blocks in de nude of the window frames. Looking at this, the choice of Obernkirchen sandstone can be considered aesthetically compatible.

¹⁸ A rough estimation of 1,4 m³ per window makes 10 m³ in total.



Figure 10: View on the high windows of the choir in Obernkirchen sandstone (photo: author, december 2005)

Shortly after WW I 17 m³ Euville limestone has been ordered. From correspondence between architect and site foreman it becomes clear that this stone was ordered to guarantee a continuation of the restoration although the architect did not like the colour in comparison with the Reffroy. It can be concluded that aesthetic compatibility has been put aside in favour of continuation of the restoration.

When the war ended it became clear that the quarries of Reffroy and St. Joire would never be in use again as a result of the intense fighting that took place in this region. For this reason and the undesired colouring of the Euville limestone, M.A. van Nieuwerkerken searched for a new stone. Coutarnoux jaune was highly recommended by *W.G. Simonis Natuursteenhandel* in Rotterdam¹⁹ 'Cette pierre n'est pas suffisamment connue, elle est d'une dureté similaire à la pierre d'Euville de marbrerie, elle est beaucoup moins dure que la Pierre de Vaurion quoique d'un grain sensiblement analogue. La couleur est sensiblement la même que celle du Vaurion clair un peu plus jaune cependant.'²⁰

¹⁹ W.G. Simonis is agent for Fèvre et Cie – société des carriés et scieries de Bourgogne.

²⁰ Hardness is comparable with Euville. Fineness of grains and density comparable to Vaurion. Colour comparable to Vaurion however a bit more yellow. GA Breda. Afdeling III nummer 76b inv.nr. 6.

Because Coutarnoux had only been quarried for 50 years and the stone had not been used in the Netherlands before at all or in restorations in France, Van Nieukerken undertook a second journey to France to visit the quarry at Dissangis where Coutarnoux (jaune) was quarried.²¹

2.3 *Dr. A.L.W.E. van der Veen*

From 1919 up till 1936 mining engineer A.L.W.E. van der Veen was appointed by the *Rijkscommissie voor de Monumentenzorg* (Rijkscommissie) to assess the exact nature and origin of stone in historic monumental buildings in order to find a matching replacement stone. Van der Veen proposed [Van der Veen, 1918] to systematically prepare thin sections for microscopic analyses. By analyzing these specimens it should be possible, in his opinion, to determine the exact place of quarrying based on the mineralogical composition. This knowledge could help to follow the *Grondbeginselen en voorschriften voor het behoud, de herstelling en de uitbreiding van oude bouwwerken*²², published in 1916 by choosing a replacement stone with exactly the same nature as the original, compatible in as many ways as possible.

Van der Veens' findings have been recorded in the minutes of the meetings of the *Rijkscommissie* and were communicated to the architects concerned with the different conservation campaigns. The early reports by Van der Veen were also published individually [Van der Veen 1920, 1920-1921, 1921-1922, 1922-1923]. In a series of articles in *Het Bouwbedrijf* from 1925 and 1926 Van der Veen summarizes his findings and strongly insists on the basic principle of choosing replacement stone of the same nature as the old, historic stone.

Looking at the reports of Van der Veen it is remarkable that most of his findings and recommendations were based upon macroscopic observations instead of microscopic observations as he suggested in his research proposal. Van der Veen often travelled to Germany, Belgium and France to visit quarries and select natural stone for individual restorations. From the archives concerning the conservation of the Church of Our Lady in Breda it becomes clear that Van der Veen was seen as an authority in the field of natural stone. In 1932 Van der Veen accompanies Van Nieukerken on his visit to the quarry of Coutarnoux to discuss the desired quality of stone.

²¹ The second reason for this trip was the selection of natural stone for the Koloniaal Instituut in Amsterdam. For this building four types of French limestone have been selected: Euville marbrier, Coutarnoux jaune, Chassignelles en Forêts de Brousse [Van Nieukerken, 1924].

²² Guidelines for conservation of old buildings.

2.4 *Limestone from the Bourgogne*

By choosing Coutarnoux jaune, Van Nieuwerkerken switched from limestone quarried in the Meuse region to limestone from the Bourgogne region. Coutarnoux was in use from 1919 to 1935, in this period approx. 140 m³ has been used for restoration work. By the end of the nineteen twenties some deliveries of Coutarnoux jaune were rejected by the site foreman Van der Meer²³ and the architect Van Nieuwerkerken because of cracks, weak spots, hard spots and an overall lack of uniformity of the stone. After a visit of the director of the quarry to Breda and an extensive correspondence between the architect, the supplier of natural stone (*Offerhaus*, Rotterdam) and the quarry owner (*Fèvre et Cie*) it was decided to undertake a second journey to the quarry of Coutarnoux in 1932.

In the mean time it became clear that the stone delivered to Breda during the past years derived from a different extraction than the one Van Nieuwerkerken visited in 1920. When visiting the quarries again, Van Nieuwerkerken and Van der Veen inspected the old extraction in search for the quality of stone that Van Nieuwerkerken selected in 1920. Although only available in small blocks and difficult to quarry, it was agreed with the director of the quarry that the old extraction would be reopened especially for the restoration of the Church of Our Lady in Breda.

To distinguish the stone from the old extraction from the regular Coutarnoux jaune, the stone extracted for restoration of the Church of Our Lady was called Coutarnoux jaune *dur sculpture*. Due to the smaller scale of extraction this stone was more expensive than the regular Coutarnoux. Already at the second delivery, Van Nieuwerkerken was complaining about the quality of the stone, therefore in the end only approx. 40 m³ stone has been used after reopening the old exploitation.

In the course of 1936 Van Nieuwerkerken discussed with Van der Veen what type of stone to choose for continuation as Coutarnoux jaune (*dur sculpture*) did not meet the desired quality. Anstrude (*dur*) jaune was advised by Van der Veen and 6.7 m³ was ordered at *Pagani & Cie*. For this order Van Nieuwerkerken totally relied on Van der Veen; he did not ask for samples and other information like he did with all earlier considered types of stone. Parallel to the order of Anstrude also 4 m³ of stone from the quarry Mont Parnasse (*banc gris dur*) in Chavignon was ordered because this stone 'comes very close to the structure of Lede stone' [Van der Veen, 1937]. Also other efforts like the search for Lede

²³ Lukas van der Meer (1881-1949) was educated by prof. Odé and appointed (and paid) by the Rijkscommissie as sculpturer at the Church of Our Lady to express the new way of restoring formulated by Odé. After the death of Vriendt in 1922 he was also appointed site foreman by Van Nieuwerkerken.

stone originating from demolition of historic buildings in Belgium and leftovers of Lede stone from the conservation of the *Grote Kerk* in Dordrecht indicate that the ideas of Van der Veen were gradually accepted by Van Nieuwerkerken. The multiple orders of new Gobertange²⁴ at Joseph Lyon in Jodoigne corresponded to the principle of replacing historic natural stone with comparable replacement stone, underlining the fact that compatibility of the replacement stone had become important for Van Nieuwerkerken.

2.5 *Limestone form the Oise region*

During World War II (WW II) the conservation continued on a small scale; special attention was given to fire protection and protection of the memorials within the church. No natural stone was ordered. In the years after WW II architect Van Nieuwerkerken and his site foreman Van der Meer continued using Anstrude, Vaurion and Gobertange. They also tried to order stone from the quarry Montparnasse in Chavignon but due to difficulties with import licenses they never succeeded. Due to these import limitations Portland limestone was offered by Keuzekamp because importing natural stone from Great Britain was easier at that time than importing limestone from France. For unknown reasons however this stone type was rejected by Van Nieuwerkerken. Shortly after WW II a small quantity of Dompierre, delivered by Keuzekamp, was used. A second order of Dompierre (4 m³) for gutter plates and sill stones was changed in Vaurion because of the availability of more suitable dimensions.

After the death of Van der Meer in 1949, C.J. Bardet took over the daily guidance of the work. It is unclear whether the new site foreman was responsible for the new types of natural stone that have been delivered in 1950 or that it had to do with the increasing influence of the *Rijkscommissie* on the choice and selection of natural stone. In 1950 and 1951 new stone types like Faverolles (roche dur), St. Maximin and Anteor were introduced and, after almost twenty years some Coutarnoux was used again.

According to the archives of the restoration of the Church of Our Lady, J.A.L. Bom²⁵ and N. van der Schaft²⁶ undertook several trips to France, some of them even accompanied by Mr. Van Nispen tot Sevenaer, director of the *Rijkscommissie*, to visit

²⁴ In the correspondence is always referred to *pierre blanche de Gobertanges débuties*.

²⁵ Chief architect at the *Rijkscommissie*. From the nineteen twenties onwards Bom worked as site foreman at the restoration of the Mary Magdalena Church in Goes, the New Church in Delft and the reconstruction of the city hall in Leiden.

²⁶ Van der Schaft was educated by Odé and appointed as sculpturer for the *Rijkscommissie*. Van der Schaft was often involved in the selection of natural stone for restoration. Van der Schaft retired in 1958 [Slinger, 1980].

quarries by assignment of the *Rijkscommissie*. In his article on natural stone [1950], Bom writes very positively about Coutarnoux and he also mentions Faverolles and St. Maximin, among others, as possible replacement stone for Lede.

In the late nineteen fifties and –sixties, only Faverolles and St. Leu d’Esserent (comparable to St. Maximin [Slinger, 1980]) were used besides some Gobertange for restoration of the church and tower. The use of Faverolles and St. Leu d’Esserent is consistent with other restorations in the nineteen fifties and sixties and suggests therefore involvement of the *Rijksdienst voor de Monumentenzorg* (RdMZ)²⁷.

Although not much information is available from the ‘in between’ restoration of the nineteen eighties, it is known from the assessment of the types of natural stone carried out at the beginning of the restoration by Van Stigt that Montanier (comparable to St. Maximin and St. Leu d’Esserent [Slinger, 1980]) had been used for replacement of the balustrade of nave and choir.

3 Replacement of natural stone during the second conservation campaign

3.1 *Research at the end of the twentieth century*

Preceding the start of the second large conservation campaign, TNO assessed the state of conservation of natural stone at the Church of Our Lady [Naldini and Van Hees, 1993]. Based on optical and electron microscopy (see figure 11 and [Larbi et al., 2003]) and freeze-thaw cycles on the ornaments was concluded that “... *the situation is alarming: due to the structural damages, the severely decayed ornaments can easily collapse. The most compromised pieces should be substituted.*”

The report by TNO and the collapse of an ornament ending at the market place adjacent to the choir were the sign to remove all freestanding, high ornaments (i.e. pinnacles and finials) on the balustrade of the choir. Following this action all lower ornaments were surveyed. In the report by Van Stigt [1993] it was advised to replace all freestanding high ornaments, including six lower, more sheltered ornaments and repair the others.

In an early stage of the conservation campaign it was proposed by Van Stigt to replace all freestanding ornaments without assessing the actual state of the individual pieces. The state of conservation of the sheltered ornaments was assessed for a second time

²⁷ National Service for Built Heritage.

from the scaffolding during execution of the restoration, less replacement and more repair resulted.

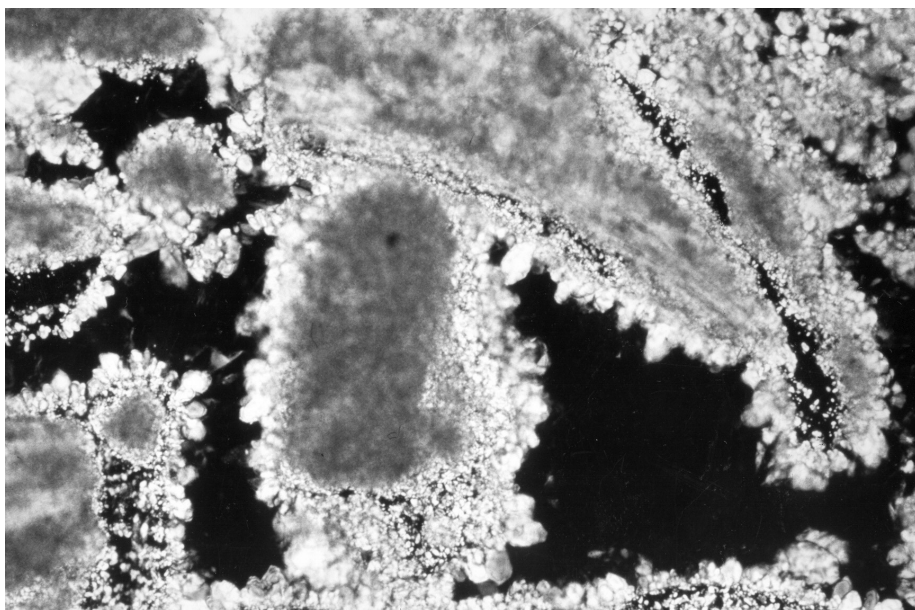


Figure 11: PFM-micro photo of a sample of oolitic limestone, size of the micrograph is 1,4 x 0,9 mm (photo: TNO)

3.2 Use of Tepla trachyte and Portland limestone

In the early discussions (May 1993) on the replacement of natural stone and the choice for a suitable stone several types of French limestone were considered: Magnier²⁸, Anstrude, Monterier²⁹. This initial preference for a limestone changed a few months later into a trachyte, a plutonic rock that colours with the existing. However, the main argument was the vulnerability of the present sculptural work to environmental conditions. This means that technical characteristics of the stone, i.e. the assumed durability, were considered more important by the architect than esthetical characteristics.

Because of satisfactory restoration results with Weidenhahn trachyte at St. John's Cathedral in 's-Hertogenbosch, this type of stone was initially proposed for to be used in Breda. However, due to upward price movements the architect was forced to look for an alternative for Weidenhahn trachyte. Because of the absence of a suitable alternative type

²⁸ Magny was meant.

²⁹ Montanier was meant.

of trachyte in Germany, the search ended in the Czech Republic where Tepla trachyte is quarried in a simple quarry near the old cloister of Tepla (founded in 1193, [Gilhuber et al, 2006]) and where this stone was used already centuries ago. The price of Tepla trachyte at that time was about 1/10th of the price of Weidenhahn trachyte. The stone was transported to the Netherlands in large cut blocks because of its low price and the lack of facilities at the quarry³⁰. In total 75 m³ was bought [Van Stigt 2007] and used for the restoration.

Tepla trachyte has also been used as replacement stone at the Cathedral of Xanten in Germany [Gilhuber et al, 2006], for the restoration of the City hall of Gouda (1995), the restoration of the Basilica of St. Willibrord in Hulst (1996-1999), the Protestant Church in Elst and the train station in Groningen (1995).³¹ Around 130 m³ of Tepla trachyte has been used in Hulst, mainly as replacement stone for Etringer Tuff stone from the 1930's [Hamelink, 2005], see figure 12.

Little repairs (i.e. single crockets) have been performed in Magny limestone instead of trachyte. Magny was used because of the higher similarity of physical properties with the existing limestone, mainly in order to avoid accumulation of moisture and consequent (frost) damage to the existing stone. So here a clear choice based on arguments related with technical compatibility led to the decision to use Magny instead of Tepla, which was considered incompatible in this situation. Another interesting consideration with respect to compatibility is to be found in the journal of the site foreman³², where it was stated that Tepla trachyte used for dripstone mouldings had to be keyed in for a maximum of 50 mm, in order to avoid the risk of negatively influencing the drying behaviour of the existing limestone.

³⁰ Oral communication by G. Overeem.

³¹ Own observation and personal communication by H.J. Tolboom and C.W. Dubelaar.

³² Restoration archives at the Church of Our Lady in Breda



Figure 12: Tepla trachyte at the Basilica of St. Willibrord in Hulst. (photo author)

After some time the quality of the delivered Tepla trachyte decreased and the price increased. Therefore the economic arguments for the use of Tepla were no longer valid. The search for a new replacement stone then led to the Isle of Portland, United Kingdom, where an oolitic limestone is quarried since Roman times. Portland limestone was used extensively by Christopher Wren for the rebuilding of numerous churches after the Great Fire in London in 1666. The selection procedure of Portland limestone included a visual examination of St. Paul's Cathedral (London, Christopher Wren, 1675-1710). In 1996 it was decided to use Portland limestone next to Tepla trachyte.

Architect Van Stigt stated that the sculptures of the choir and chapels are visually connected in such a way that unity of material was desired, therefore Portland limestone was only used at the (north side) of the nave, not interfering with the sculptures in Tepla trachyte of the choir. He considered both types of natural stone to be aesthetically incompatible. In total 7 m³ of Portland limestone were used [Van Stigt, 2007]. Since the restoration campaign has ended, replacement of natural stone in case of maintenance is also performed in Portland limestone [Massop, 2002].

3.3 *Repair*

Many ornaments were kept in place partly and only single (lead) finials and crockets have been replaced. Many crockets were moulded using Monulit mortar (see figure 13)

The elevations in white stone have been repaired with Monulit mortar and, where necessary, individual blocks have been replaced by new Gobertange blocks. At some locations replacements have been made in Tepla trachyte. This was done especially in the walls of the choir just above ground level because of the high salts load due to urinating in the weekends and the fish stalls of the weekly market. A higher resistance to salts was attributed to trachyte. Although the stone itself indeed is assumed to be less susceptible to salts it is unknown what the consequences are of the combination of Gobertange masonry with individual blocks of Tepla trachyte. Due to different pore sizes and pore size distribution the transport of (salt containing) moisture through the wall, the drying behaviour and consequently the salt crystallization cycles can not easily be predicted; therefore there are some doubts about the technical compatibility of this intervention.

Also other components of the intervention, e.g. the use of Monulit mortar for stone repair leave some doubts as to whether compatibility was thought of: the components of the repair mortar may lead to the formation of hygroscopic calcium chloride³³, a very hygroscopic salt.



Figure 13: Moulding crockets with Monulit mortar (photo: Architectenburo J. van Stigt b.v.)

³³ See Rockview report 971220

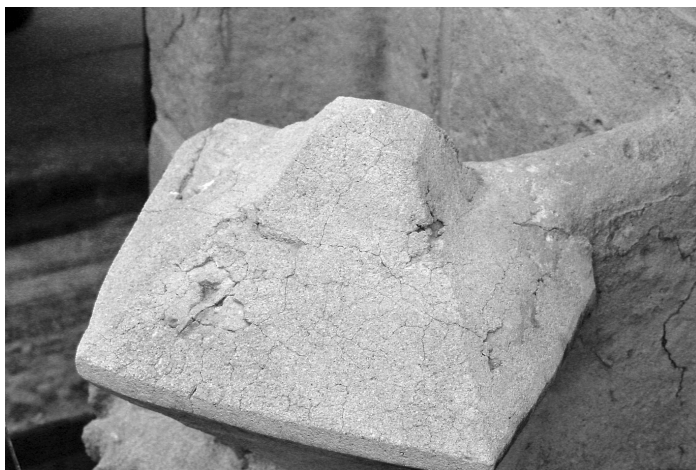


Figure 14: Incompatible use of Monulit mortar. (photo: author)



Figure 15: Compatible use of Monulit mortar. (photo: author)

For the time being, i.e. ten years after execution of the repairs, it can be observed that the repairs are still intact and aesthetically acceptable. Pre-requisite for a durable repair however is the application in a sufficient thickness (see figure 14 and 15).

An important observation made by Van Stigt was further that the hard and stiff cement re-pointing, applied during the previous campaign had provoked damage to the surrounding Lede and Gobertange stone (and hence could be considered incompatible), see fig. 16.



Figure 16: South façade transept. Consequence of use of incompatible re-pointing: damage to Lede stone – situation 1991. (photo: Rob van Hees)

4 Discussion and conclusions

In this chapter both 20th century restoration campaigns will be discussed trying to assess how durability and compatibility were dealt with.

4.1 The Van Nieukerken campaign

At the beginning of the twentieth century the Church of Our Lady in Breda had degraded so far that an all-embracing conservation campaign was deemed to be necessary. The campaign included the removal of the small dwellings built around the choir and the reconstruction of late medieval sculptural work. Father and sons Van Nieukerken wanted to recreate a unity of style and therefore strived for a unity of material to support this image. Into their opinion durability, capacity to blend in the existing fabric and tooling capacities were equally important properties of a replacement stone.

In the first quarter of the 20th century colour, hardness³⁴ and density seem to be the most important criteria for selection of natural stone for the restoration of the Church of Our Lady. High hardness and high density were described as positive properties. Apart from (too low) density, (high) transportation cost sometimes has been used as a criterion for rejection of types of natural stone. There was no (strong) believe in laboratory tests although those were available. Selection was based on visual examination.

In terms of compatibility it is clear that aesthetic compatibility (colour, structure, weathering colour) for the Van Nieuwerkerkens was the most important factor in choosing replacement stone. No clear attention was paid to the technical aspects of compatibility. Material properties were looked at, but only regarding the assumed durability of the replacement stone itself, not in relation with the existing stone.

4.1.1 *Durability in practice*

From the archives it is not clear what the expectations in terms of durability and life expectancy regarding the chosen types of natural stone were. Looking at the positive terms regarding Reffroy limestone in the report of the study trip of Van Nieuwerkerken to the North of France and Belgium it is very probable that the architects expected a longer service life than 60-80 years³⁵. Based on his visit to several (restoration) projects executed in Reffroy/St. Joire up to 40 years before, Van Nieuwerkerken judged the stone to be durable. Although his judgment was positive, in Breda repairs were necessary already 30 to 40 years after application (i.e. in 1951 a finial has been placed on the balustrade of the choir aisle) and almost all the unsheltered sculptural work was in need of replacement within 60-80 years. Looking back to the procedure, some explanations can be thought of:

1. The quality of stone delivered to Breda was lower than the quality delivered to other sites;
2. The environmental conditions differed (Breda versus other places);
3. The environmental conditions changed over time;
4. The degradation of the stone was far less in the first 30-40 years than in the second 30-40 years;

³⁴ In Dutch, the term 'hardheid' was used. Hardness is the literal translation. Hardness (and 'hardheid') refers to various properties of matter in the solid phase that gives it high resistance to various kinds of shape change when force is applied. In terms of natural stone is mostly referred to the scratch hardness (Mohs scale), but that was not the intention here. Most probable they meant compressive strength.

³⁵ In general the architects Van Nieuwerkerken practised a very monumental and long lasting kind of architecture therefore it may be assumed that their intention was to restore not only for a number of decades.

5. Van Nieuwerkerken and others were not able to make a sound assessment of the condition of the stone in situ;
6. The sculptural work in Breda differs in form and dimensions from the sites visited by Van Nieuwerkerken.

Ad. 1.

There are neither indications nor proof for this hypothesis. Also other restoration campaigns during this period are not known to have suffered from malpractices.

Ad. 2.

Environmental conditions differ from place to place because it is always a combination of, for instance, air pollution, rain load and freeze-thaw cycles through the seasons. Although exact information is not available it is not likely that the conditions in Breda are noticeably worse than all the places Van Nieuwerkerken visited like the Meuse region, Reims, Ypres, Ghent and Bruges.

Ad 3.

The main cause for degradation of limestone is sulphation [Naldini and Van Hees, 1993]. Although exact figures changes in the concentration of sulphur dioxide in the air are missing it is unlikely that an increase caused so much damage that it was beyond Van Nieuwerkerkens' expectations.

Ad 4.

Several authors have written on the degradation of (sandy) limestone (see for a literature overview Naldini and Van Hees [1993]). They all propose slightly different models for crust formation and stone decay. Combining the models and the findings of Naldini & Van Hees results in the following-list of successive mechanisms that may have caused the degradation of the sculptural work at the Church of Our Lady in Breda:

- Formation of gypsum crust
- Gypsum crust accommodates particles from the air
- Damage to the gypsum crust
- Water penetration
- Frost action
- Loss of material coherence

From the occurrence of the first damage to the gypsum crust on, the material becomes more susceptible to accelerated degradation; this is especially the case for free standing sculptural work due to its all-round weathering.

Regarding to the observations of Van Niekerken and his judgement that the Reffroy limestone was durable it can be assumed that he only evaluated examples that reached the first or second stage of degradation. He was not able to foresee the next stages of degradation leading to a much more pronounced material loss.

Ad 5.

Although Van Niekerken did his best to investigate the quality of natural stone by visiting the quarry and different sites he was not able to assess the quality according to nowadays knowledge. Without microscopic studies, freeze tests and other experiments it is difficult indeed to judge the durability of a replacement stone in a sound way.

Ad 6.

Although most sites visited by Van Niekerken only concerned simple masonry elevations in Reffroy, on his trip through France he also visited the cathedral of Rheims with sculptural work at least as detailed as in Breda. Nevertheless it may be assumed that when Van Niekerken based his positive judgment with respect to Reffroy limestone on the general image of the examples he visited, he did not realize the possible difference between the weathering of masonry and (free standing) sculptural work.

4.1.2 Compatibility

The use of Lede stone from demolition of historic buildings in Belgium and of leftovers of Lede stone from the conservation of the *Grote Kerk* in Dordrecht shows that, probably influenced by stone specialist Van der Veen, the importance of compatible replacement stone was gradually accepted by Van Niekerken.

4.2 The Van Stigt restoration

Because of the term 'technical restoration' used by Van Stigt it might be expected beforehand that his choices for replacement of natural stone would have been based on technical rather than on esthetical compatibility. Van Stigt made further use of the results of (scientific) research on the state of conservation of the building, which can be considered a step forward if compared with the past situation.

4.2.1 Technical compatibility

A good example of taking into account technical compatibility is the use of technical arguments for the choice of Magny for individual replacement of crockets.

Important observation made by Van Stigt was further that the hard and stiff cement re-pointing, applied during the previous campaign had provoked damage to the

surrounding Lede and Gobertange stone (and hence could be considered incompatible). However, even van Stigt is not consequently following this line: Although the free standing ornaments in Tepla trachyte 'do not harm the existing', this stone can hardly be considered technically compatible with the existing surrounding limestone. The mineralogical composition and physical properties differ so much that this might on the long run result in unwanted damage to the existing stonework due to unpredictable moisture movements. Although only keyed in for 50 mm the connection between the Tepla trachyte of the new dripstone mouldings and the existing limestone could be problematic and should be monitored.

4.2.2 Durability or compatibility

Although Van Stigt took (technical) compatibility into account in his considerations, it is also clear from for example the change from limestone to trachyte as replacement stone, for reasons of better durability, and finally back to limestone (Portland), that he did not consider compatibility a clear directive. For esthetical reasons, Van Stigt did not use Portland limestone next to trachyte, but here were no real compatibility considerations towards the original materials involved.

At this moment, ca. 15 years after the conservation, no incompatibility damages are visible, however it is still too early for a sound judgment of the choices Van Stigt made.

4.3 Conclusions

In both restoration campaigns the architects have been using sometimes arguments of durability, sometimes of compatibility. There is however no clear and consequent line to be found in this respect in either of the two restoration campaigns.

Theoretically, two extremes may be followed for the choice of replacement stone:

- Stone similar to the authentic (that theoretically might be the most compatible³⁶ solution);
- stone that is mainly durable on its own.

For the second line however, experience has shown that sometimes interventions which proved durable (in the sense that the materials used did not decay), were not compatible with the original fabric and created additional or new problems.

³⁶ Compatible is defined as: not causing any damage (in a broad sense, ranging from technical to esthetical and historical) to the existing fabric and being as durable as possible under that condition.

It may be argued, that if a sound balance between 'as authentic as possible' and 'as durable as possible' is strived for and ultimately obtained, both could be considered aspects of one and the same concept: compatibility.

If there is any historic line to be distinguished in the two restoration campaigns, it might run from attention to aesthetic compatibility, over durability to technical compatibility.

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