CATHEDRAL NORTE DAME IN PARIS – THE INSCRIPTION OF THE SOUTH TRANSEPTS FAÇADE: MEDIEVAL RELICT OR 19th CENTURY RECREATION?

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ABSTRACT:

While non-destructive 3D technologies offer outstanding possibilities for analysing shape and similarities in architectural details, and for the monitoring of weathering effects, it has so far been used only rarely for these purposes. This paper shows the application and analysis of high resolution, handheld, optical tracked laser scanning on an inscription at the cathedral of Notre Dame in Paris. The transept's south façade carries a latin inscription dating from 1258, and the common research opinion is that the inscription was copied and renewed during the mid-19th century restoration. In the course of an on-site research campaign, some doubt as to the veracity of this theory arose. Essential questions regarding the inscription concern the workflows of both medieval craftsmen and those from the 19th century. The project's aim was to analyse the inscription for its shape and for any traces left by the craftsmen. Another key question focussed on the originality and authenticity of the inscription. The analysis of the high-resolution 3D data set has confirmed the initial visual impression of differences between the stones and shown that most of the inscription is the 13th century original with only a few parts replaced. The analysis also revealed that the ribbon and the letters must have been carved before the stones were placed. An investigation using historical transcripts, comparative examples and contextual reflections with a detailed analysis of the individual letters also revealed possible changes in the wording of the inscription made during the restoration. A discussion of the possible variants supported by virtual visualisations is also presented.

1. INTRODUCTION

Non-destructive high resolution 3D-recording technologies offer outstanding possibilities for analysing the shape and similarities of building decorations such as sculptures or inscriptions. These methods are especially useful for monitoring weathering effects, but have so far been used only rarely for these purposes. This case study focusses on the application and analysis of high resolution, handheld, optical tracked laser scanning of an inscription at the cathedral of Notre Dame in Paris. The cathedral is one of the most famous UNESCO World Heritage sites in France and one of the few whose building history is well known. As part of the research project "Mittelalterliche Portale als Orte der Transformation", funded by the German Federal Ministry of Education and Research, the portals of the cathedral's transept have been investigated along with portals of several other European cathedrals.

The transept's south façade reveals a unique characteristic: the pedestal carries a Latin inscription dating from the time of construction, 1258 (Fig.1). The inscription shows not only the date and the master architect's name – unusual for medieval times – but it is also in a prominent location and quite elaborately crafted. The inscription itself is approximately 8.9m long and 8 cmm high, and the depth of the ribbon itself is 6mm. The 110 letters are carved in relief on to ten ashlar stones (Fig. 2), and the latin wording is + ANNO . DNI . M . CC LVII . MENSE FEBRVARIO . IDVS SECVNDO [H]OC . FVIT . INCEPTVM CRISTI . GENIT CIS HONORE KALLENSI LATHOMO . VIVENTE . JOHANNE. MAGISTRO.

According to current research (Albrecht et al. 2019), it was previously believed that the inscription was copied and renewed during the mid-19th century restoration campaign carried out by Eugène Viollet le Duc (Kimpel, 1971). However, during an on-site research campaign which also involved a detailed visual analysis of the inscription, some doubt as to the veracity of the replacement theory arose: The craftsmen's traces differ between the stones and only a few of them show evidence of typical 19th century tools. Essential questions regarding the inscription therefore concern the workflows of medieval and 19th century stonemasons: are there differences in how the stones were treated and carved, and were the stones carved before or after they were placed?

By the middle of the 19th century, knowledge of medieval tools and manufacturing and construction techniques was already advanced (Hubel, 2011; Völkle, 2017; Viollet le Duc, 1854–1868). A better understanding of the construction workflow, however, can still help to answer further questions regarding not only the inscription, but also the transept as a whole. The project's aim was therefore to analyse the inscription for its shape, and also for any traces left by the craftsmen. Another key question focusses on the originality and authenticity of the inscription.

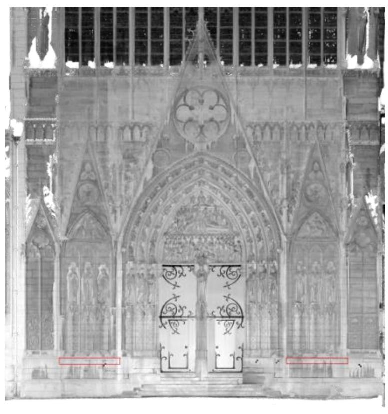

Figure 1. Orthoimage South Transepts Portal, Notre Dame.

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Figure 2. Orthoimages of the high-resolution models of the ten stones of the inscription. Red framed stones: 19th century replacement; yellow framed stones: medieval original.

2. DOCUMENTATION WORKFLOW AND POSTPROCESSING

To ensure the aims of the project were achieved, a precise 3D documentation with a submillimetre resolution was needed. A resolution of 0.3 mm was provided by the T-Scan2 handheld optical tracked laser scanning system from Steinbichler Optotechnik GmbH (now: Carl Zeiss Optotechnik GmbH).
The scanning device has two parts, an optical tracking system and a handheld scanner. The tracking system consists of a camera beam incorporating three infrared cameras, whilst the handheld laser scanner features several infrared diodes which enable tracking (Fig. 3). In addition a controller and computer are necessary. The software used to operate the system is T-ScanPlus 9.00. The tracking system’s three cameras define a measuring volume (ca. 2.00 x 3.00 x 2.30m) in which the handheld scanner can be tracked. By scanning the surface in 90mm wide stripes the entire object can be recorded without the need to register every single scan (Steinbichler, 2013). Due to its length, scanning of the inscription and surrounding parts of the base of the south transept’s facade had to be carried out in several sections. For each position, the tracking system was moved so that overlapping areas could be scanned, enabling each data set to be registered together. The two parts of the inscription, the western and the eastern part were recorded separately and later aligned to the point cloud from a terrestrial laser scanner (Faro Focus3D), thus ensuring that the accuracy the overall geometry is correct.
The data sets were later postprocessed using the scanner’s own software, T-ScanPlus 9.00, to do a best fit constrained matching. After the matching and filtering (outliers), the point cloud was triangulated with a max. triangle edge length of 0.5mm.
The resulting models, one for each side (east and west), were exported as .stl files and imported into Geomagic Studio 2017 for curvature-dependent small hole filling. For further analysis the resulting .stl files were imported into aSPECT 3D v.16.3 to create cross sections and orthoimages. The base plane was defined for each model on the surface of the pedestal zone.

Figure 3. Steinbichler T-Scan 2: Optotrak Tracking system and handheld laser scanner. (Rahrig/Drewello 2012)

3. 3D DATA ANALYSIS

Unlike previous studies conducted on inscriptions or graffiti, the main focus of this investigation was not simply on reading the inscription (Tenschert et al., 2019; Papadaki et al., 2015) but answering questions concerning the medieval and 19th century production and setting workflows, and the craftsmen’s choices in tools and the shape of letters.
To find answers to these initial questions, the 3D data sets were analysed using multiple approaches:
The textureless surface geometry was used to visualize letter shapes as well as differences in stone variety and surface treatment, particularly the stonemasons’ tool traces.
High resolution orthoimages were generated from the surface geometry models in aSPECT 3D v.16.3 to give distortion free and dimensionally stable views of both the entire models and single letters. These orthoimages were also used to define and analyse the base lines of the ribbon.

3.1 Inscription’s framework: the ribbon

To further analyse the dimensions of the ribbon, cross sections (horizontal and vertical) and a deviation mapping from the base plane were created in aSPECT 3D v.16.3 using a level mapping in 1 mm steps. This helped to see if the stones are set correctly or slightly rotated, if the ribbon is the same depth throughout the inscription, and how the location of the stones compares to the surrounding areas (i.e., is the location precise or are there significant deviations between the stones). The sections also help answer questions of working technique, positioning of the stones and the overall precision of execution. To gain information about the depth and shape of the ribbon, a vertical cross section was made every 5mm. The resulting vector lines were exported from aSPECT 3D in .dxf format and used in AutoCAD 2019 to define the average depth of the ribbon for each stone. The inscription’s background’s level is approximately 6.0mm (Fig. 4).

This depth varies only slightly, in the submillimetre range, on single stones, but bigger deviations in the millimetre range can be detected in areas where weathering has caused greater damage. No significant differences in the depth and shape of the ribbon can be detected between the replaced and the original stones. The letters themselves take up the base level of the stone blocks, and there are minimal differences in the levels between the stones due to the positioning process. Some stones are a little twisted relative to the base level, or are set back a few millimetres from the base level of the pedestal. These deviations are visualised in Figure 5, which shows a 3D model of the entire inscription using coloured contour lines as a depth map.

As seen in the orthoimages and vertical cross sections, there are small differences between the heights of the base lines of the ribbon, for example stones 8 and 9 show a difference of 3 mm (Fig. 6). If the inscription had been carved after the stones had been positioned on the construction site, and the ribbon initially sketched with a ruler and then carved not just on a single stone but across the stones’ borders, these differences would not be visible.

Therefore the stone blocks with the inscription must have been premanufactured in the workshop and positioned afterwards. Stones 1 and 2 are positioned very precisely regarding the base lines of the ribbon, which show almost no deviation in height. This observation supports the initial on-site impression - due to the different stone type and the differences in the letters - that these two stones might have been replaced. The lack of deviation might be because of precise levelling in 19th century.

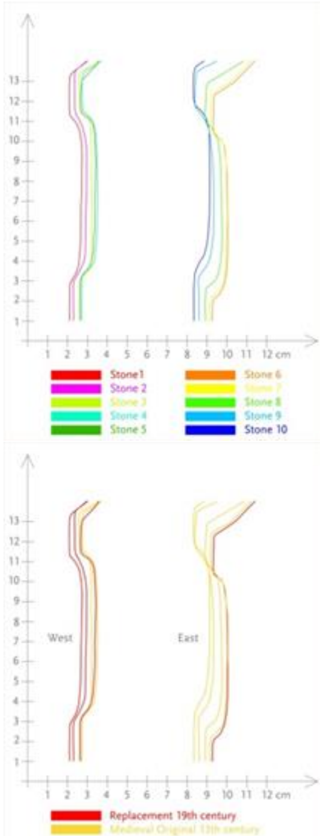

Figure 4. Average vertical cross sections of every stone (above), comparison between Middle Ages and 19th century

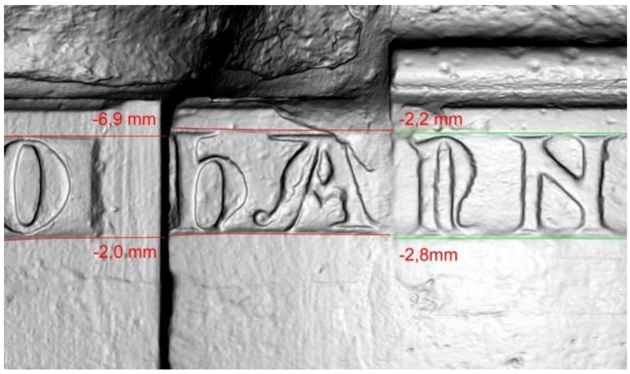

Figure 6. Deviation in the ribbon’s base lines between two stones

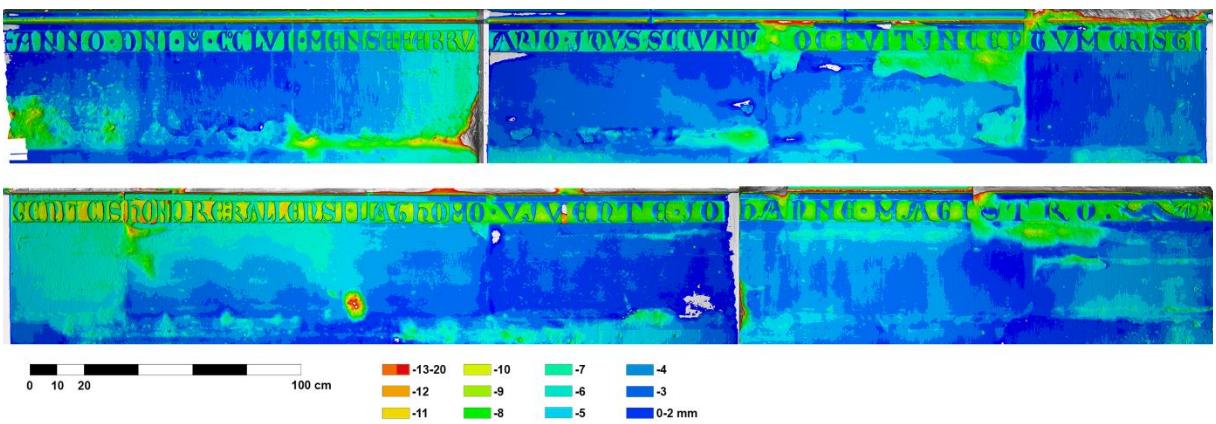

Figure 5. Depth map: western area (above), and eastern area (below). The colours show the deviation from the pedestal surface’s base level (dark blue) in 1mm steps to a depth of 2cm (red).

3.2 Craftmen’s tool traces and shape of letters

The textureless 3D model reveals traces of the craftsmen’s tools far clearer than photographs. With appropriate raking light. applied virtually, some of the stones show traces of typical 19th century stonemason’s tools, for example the vertically ordered lines are evidence of the use of a drove chisel (Völkle, 2017).
To discuss the design and manufacturing technique of the inscription properly it is necessary to examine the object in detail. The characters are spread over the entire pedestal and sit on an engraved base ribbon. The surrounding material has been carved out leaving the letters protruding and creating a ribbon. The angle between the characters and the background is not strictly 90 degrees, which would have made the optical contrast much bigger and inorganic. Instead, the letters are carved with a slight and smooth transition to the background, making them appear more organic and natural (Fig.7). It would have been considerably easier to notch the letters into the stone and indeed, this technique is much more common, so the approach chosen by the stonemasons in Paris distinguishes the Notre Dame inscription as something extraordinary (Netz, 1982).

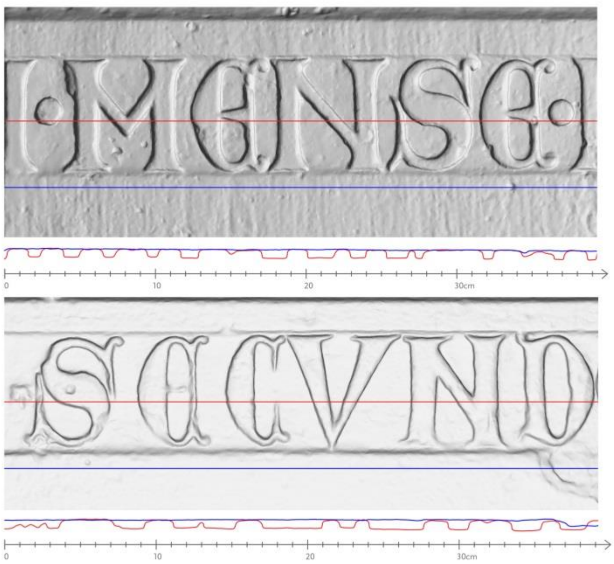

Figure 7. Horizontal cross-section, red through letters, blue base level of stone, 19th century above, medieval below.

On site it was quite obvious that a variety of different limestone types have been used in the pedestal. Some contain round inclusions, which can be seen clearly in the 3D model. These stones also show surface processing which seems typically 19th century, as mentioned above. Therefore the hypothesis after the on-site campaign was: The only original medieval stones are 3,4,7,8,9 and 10 (see also Fig. 2).
To verify this theory a further analysis of the letters was necessary. To find differences and characteristics in style of the gothic majuscules and their processing, the letters were grouped according to their location on either medieval or replaced stones. Afterwards the characters were sorted alphabetically and arranged in tables.
All of the letters fit perfectly within the ribbon’s borders, with none of them intersecting the base lines, so the letters are all quite similar in height. However, the medieval letters vary tremendously in width whereas the 19th century examples stay within a much more limited size range. For all types of letter it can be observed that there are differences in the shapes of the strokes and serifs between the medieval and newer 19th century letters. Especially fruitful were the comparisons of the *A*, *E* and *V* characters.

The *A*s show significantly different sizes and shapes (Fig. 8). The only 19th century *A* is very static and geometric compared to the medieval ones. It has a broken central beam and its top beam is hook-shaped to the left. The left stroke is curved and has an arched swelling, and the inner contour is rounded towards the central beam. The medieval *A*s are all very different; all except one are designed with a double left shaft, the outer one with an arched and curved swelling and the inner one with only a thin line. The swashes have varying hook-shapes and do not resemble each other in detail. One *A* is also executed with a broken central beam. The *A* which has no second left beam has a peculiarity in the design of the central beam. It has been replaced by a vertical arch, leaning against a short horizontal attachment. The widths of the *A*s dated to the Middle Ages range from 6.69 to 10.73cm, with a largely constant height of 8cm.

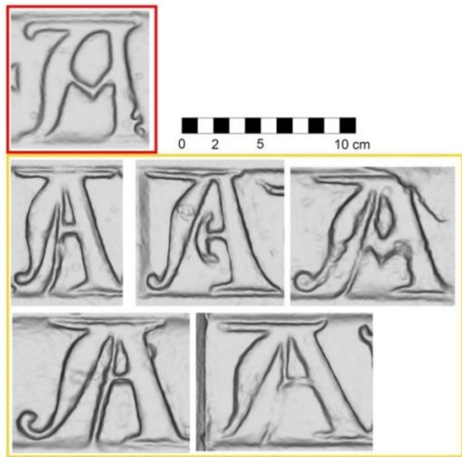

Figure 8. Table of *A*s, red frame: 19th century, yellow frame: medieval originals

The 19th century *E*s are constructed geometrically, the ones on the replaced stones can be mirrored along the middle axis, as shown in Fig. 9. The central beams are wedge-shaped and the letters are closed. At the ends there are hook-shaped, curved and knot-like endings which can be connected with a vertical line. The inner contours above and below the central beam are carved uniformly. The widths of the 19th century *E*s differ by only a few millimetres (between 5.20cm and 5.42cm), a variation of just 4%. In contrast, the medieval letters are clearly designed differently: Their swashes and ends are all distinctive, they protrude differing distances and do not have the same knot-shaped terminations as the 19th century characters. The variance in letter width is 22% (4.91cm to 6.33cm).
The 19th century *V*s are constructed comparably strictly around the vertical middle axis and the variation in width (19%) is only half that of the medieval characters (40%, between 7.50cm and 12.52cm) (Fig 10). The transition from the angled strokes to the serif is also curved on the newer stones, whereas in the medieval examples it is asymmetrical, the legs are not curved and the transition from the bevel to the top strokes is triangular.
Another characteristic of the medieval letters are the “lettre fleuries”, small floral details. These playful details can be found on the *A*s, *I*s and *R*s and correspond in style to the small dragon at the end of the eastern ribbon (Fig. 11). These decorative characteristics are derived from images found in illuminated medieval manuscripts. Overall, it is clear that the medieval letters are carved in a much freer manner than the 19th century ones. The newer letters have shafts that are strictly perpendicular to the ribbon’s base line, while the originals vary around that 90° angle. These variations make the medieval

letters look more natural and individual than the ones on the replaced stones. Here, too, the findings suggest a painted and subsequently elaborated medieval font design, in contrast to the geometrical font of the 19th century, for which it is obvious stencils were used.

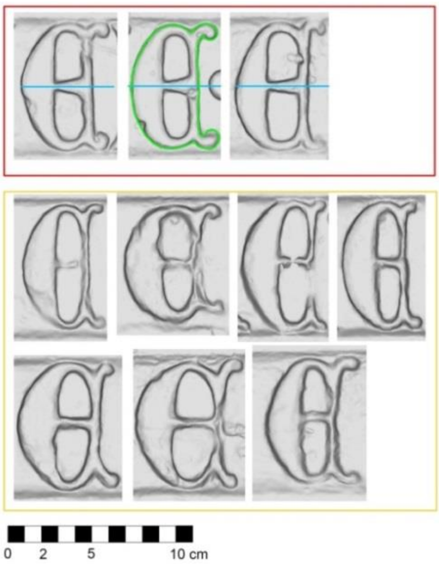

Figure 9. Letter *E*s: above in red frame 19th century *E*s; blue: middle axis; green: mirrored parts; below in yellow frame: medieval *E*s.

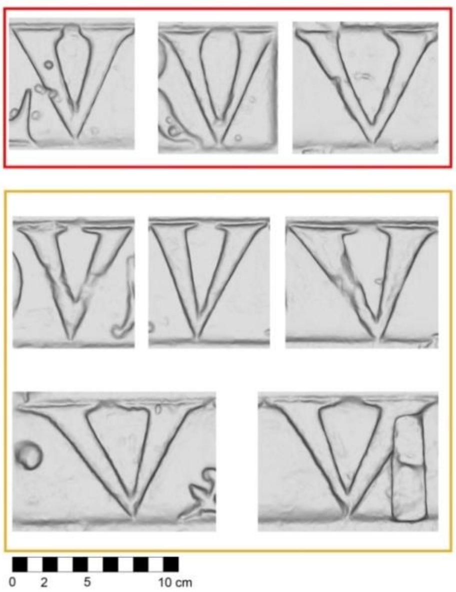

Figure 10. Table of *V*s, red frame: 19th century; yellow frame: medieval

Figure 11. Medieval "Lettre Fleuries" and dragon

3.3 Inscription's content

Further observations from the precise analysis raise further questions about the 19th century approach to the content. The letters on stone 2 are arranged tightly and become narrower towards the portal, and the spaces between them become almost non-existent (Fig. 12). The *I* at the beginning of the stone even had to lose its left serifs during the stone positioning process. Why are the letters so crowded, when the medieval ones are so much more spacious and freely distributed along the length? Did the 19th century craftsmen simply make the letters of the first stone too wide and the spaces between them too generous? Were there abbreviations in the original not included in the replacement? Was there a different number, or even different numerals used? (Fig. 12)

The theory that the letters of the first stone are too wide can be dismissed, and the distances between them are also not significantly different from those on the medieval stones 3 and 4. It is possible that the phrase Anno Domini was originally abbreviated differently, for example AD, however, the abbreviation DNI was just as common in medieval times (Cappelli, 1928). Considering the hypothesis that the original might have shown a different number or used other numerals, it must be noted that old written transcripts of the inscription also mention the number 1257 (Corrozet, 1581). Also, while Roman numerals were still commonly used in the 13th century, it would certainly have been more space-saving to use Arabic numerals. These had already been known in Europe for about two centuries in medieval writing rooms, and used in their handwritten manuscripts. Kunitzsch refers here to the two Isidor manuscripts, the Codex Vigilanus of 976 and the Codex Emilianus of 922, which were the first to illustrate Arabic numerals in the West Arabian form and makes convincing arguments as to their use in 12th century manuscripts (Kunitzsch, 2005). However, Arabic numerals have not been found in building inscription dates before the 15th century. It must therefore be assumed that since the problem of space is not due to the content or shape of the first stone, it must be due to the two words on the second stone. The first part of FEBRVARIO can be assumed to be correct because it is adapted to the medieval stock ARIO on the third stone; the word MENSE remains. In the manuscripts and inscriptions of the Middle Ages it was not unusual to abbreviate mense as m or ms (Capelli, 1928). For example, a contemporary and content-related building inscription on a gothic parish church in Audenarde, Belgium, from 1234 uses M to abbreviate MENSE (Stein, 1909; De Borchgrave d'Altena, 1962; Devos, 1978; Van den Abeele-Bellon, 1979).

There are some sources that may support the thesis that the known transcripts of the inscription before restoration are not epigraphically correct. For example they wrote out Anno Domini completely, Corrozet in the 16th century (Corrozet, 1581) wrote domini instead of dni for clarity, cristi is transcribed with an H, and genitricis is written out in full. The last two examples were changed in the 19th century and could therefore also have differed in spelling in the 16th century, but the missing H in Johanne from a medieval stone confirms that the 16th century transcriptions were not always correct. The situation is similar with transcriptions from the early 19th century, which ignores the abbreviation Dni for Domini or abbreviate Secundo (Whittington, 1809; Galignani, 1846). This is why it seems at least possible that the word mense was abbreviated in the medieval inscription and that this gave rise to the problem: using the abbreviation, with the average width of the medieval letters and a wider space between them, the letters could still be distributed well on the stone without having to crowd each other (Fig. 12).

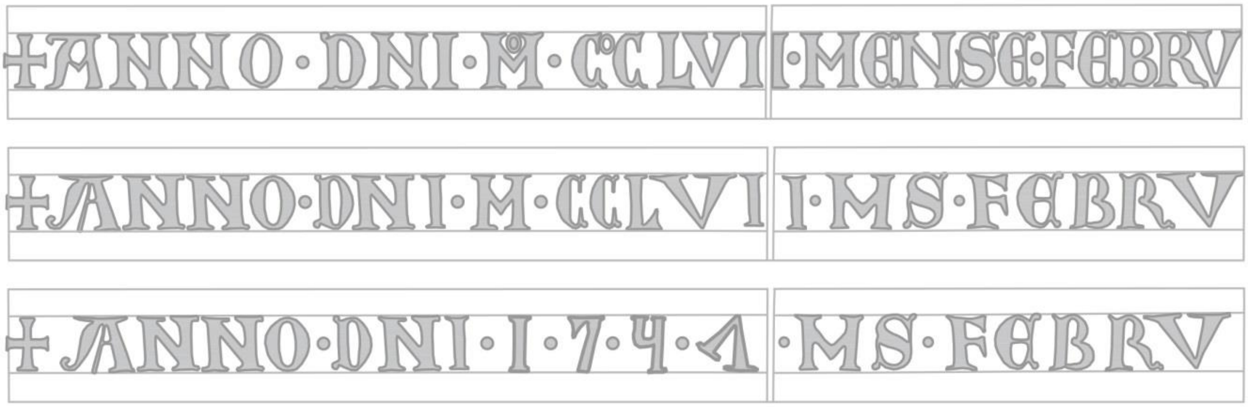

Figure 12. Graphical reconstruction of the inscription’s first two stones; above: existing stock of the 19th century replacement, middle: Reconstruction of the medieval stock using the medieval letters and the abbreviation MS instead of MENSE, below: Reconstruction of the medieval stock using Arabic numerals.

Given the historical tradition and the possible abbreviations, which of the variants is the most convincing? To investigate possible solutions, reconstructions have been made using the actual size of stones 1 and 2 and examples of medieval letters taken from other parts of the inscription. To reconstruct the variation with Arabic numerals, models from the handwritten manuscripts were used, customised in the overall style of the medieval inscription.
Figure 12 shows, at the top, the existing stones with the 19th century letters. In the middle a version using medieval letters and an abbreviation is displayed. It shows that the text, with the slight change from MENSE to MS, fits very naturally in the available space, and the letters don’t seem so tightly arranged as in the 19th century piece. To ensure the letters fit into the given space the widest medieval letters of each type were used for the virtual reconstruction. The reconstruction below goes one step further and uses Arabic instead of Roman numerals. It fits quite satisfyingly according to the space and dimensions of the ribbon, but using Arabic numerals in the middle of the 13th century would have been revolutionary and contradicts the prevailing research that says they weren’t used on building inscriptions until the 15th century. Considering these facts and the historical traditions the reconstruction of the original wording “ANNO DNI M LCCII MS FEBRU[…]” appears the most convincing option.

4. CONCLUSION

The detailed analysis of this high resolution 3D documentation of a medieval inscription has made a huge contribution to answering questions of the history of the cathedral of Notre Dame in Paris; in particular regarding the effects of the 19th century restoration on the south transept inscription. The analysis of the 3D data set has not only confirmed the initial visual impression of certain differences between the stones, but has also shown that most of the inscription is still the 13th century original and that only a few parts were replaced during the restoration. The 19th century stones show significantly different characteristics in both the appearance of the letters and surface treatments; these tool traces are only visible in the 3D data. Although the 19th century stonemasons closely imitated the manufacturing technology and workflow of the medieval craftsmen regarding the geometry of the ribbon, the high resolution 3D surface model reveals small differences in the surface due to the use of more modern tools such as the drove chisel. In addition, the shape of the ribbon and the letters have also been analysed using the 3D data, with virtual raking light revealing the variety of tools used to work the stone surface.
Analysing the depth of the ribbon and the letters using virtual contour lines and cross sections was fruitful in providing insights regarding deviations between the single stones and the precision of the craftsmen in staying within a very limited deviation range from the 6mm frame. These findings enable conclusions to be drawn regarding the differences in manufacturing processes and techniques used in medieval times and the 19th century.

The close analysis also revealed important findings regarding the precise location/positioning of the inscription. Small differences in the ribbon framing the letters at the joins between stones show clearly that the ribbon and the letters must have been premanufactured in the cathedral’s workshop before the stones were placed on the medieval construction site. An investigation using historical transcripts, comparative examples, building archaeology and contextual reflections, combined with a detailed analysis of the individual letters in the 3D data have also revealed possible changes in the wording of the inscription made during the restoration in the mid-19th century. Subsequently, a discussion of the possible variants supported by visualisations led to a convincing result that the wording of the medieval original might have been changed in 19th century and therefore led to the tightly arranged letters on stone 2.

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