Connecting Structure and Aesthetics

Exploring the added value of flying buttresses in Gothic cathedrals.

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AR2A011 Architectural History Thesis

MSc 2

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Abstract:
While it has been identified as a key architectural marker for the Gothic building style, the flying buttress is not just an ornamental addition in Gothic cathedrals. It was developed initially as a way to divert the horizontal forces produced by the roof vaults to the ground, through the buttresses. However, it is difficult to say with some cathedrals if the flying buttresses are added for the stylistic or for the structural reasons. Research into pre-modernistic architecture is generally lacking and it is important to decipher the building techniques of the past to be able to learn from them in the present. To discover the added value of the flying buttress the St John Cathedral in Den Bosch has been chosen as a case study because it started as a roman church without flying buttresses, but was redesigned into a Gothic cathedral with them. To discover what function this particular element holds for the St John will shed more light on the element in general.
Research has shown the flying buttresses of the St John Cathedral to be structurally necessary, though perhaps a little exaggerated for the height of the roof, by choosing for a double layer of flying buttresses. The choice for this second tier probably lies in the aesthetic of the Gothic style the cathedral is meant to fit into or in the copying of French cathedrals. The figurines on top emphasize the ornamental nature and give a special feature to this particular cathedral.

Key words: Flying buttress, Gothic architecture, Gothic cathedrals, St. John Cathedral, Den Bosch

1. Introduction:

The flying buttress is an iconic element found in the design of Gothic cathedrals like the Notre Dame in Paris. Though it might look like an ornament added primarily for aesthetics, it can also have a structural function. Discussions on the exact purpose of this building element have differed over time and recently the subject has been revisited with the help of contemporary engineering technology[1].

This thesis delves into the possible reasons why this particular building element was added to cathedrals during the Gothic architectural period.

Research into pre-20th century structural building methods has become more and more necessary in the field of monumental preservation, as it can provide information on

[1] William W. Clark and Robert Mark, "The First Flying Buttresses: A New Reconstruction of the Nave of Notre-Dame De Paris," *The Art Bulletin* 66, no. 1 (1984): 47-65, https://doi.org/10.2307/3050392.

the best strategy for restoration. However, this kind of research is still lacking[2]. Especially in the Netherlands, historic architecture and its methods and characteristics, are under-researched, mainly because structural heritage originating from pre-20th century is barely taught at universities in the architecture studies[3], which leads to very few scholars with architectural and structural knowledge taking an interest in the buildings in this time period. It is seen as more historically than constructively relevant and research is often left to history experts, which results in an aesthetic and external evaluation, without providing information on the inner structural workings of the building[4].

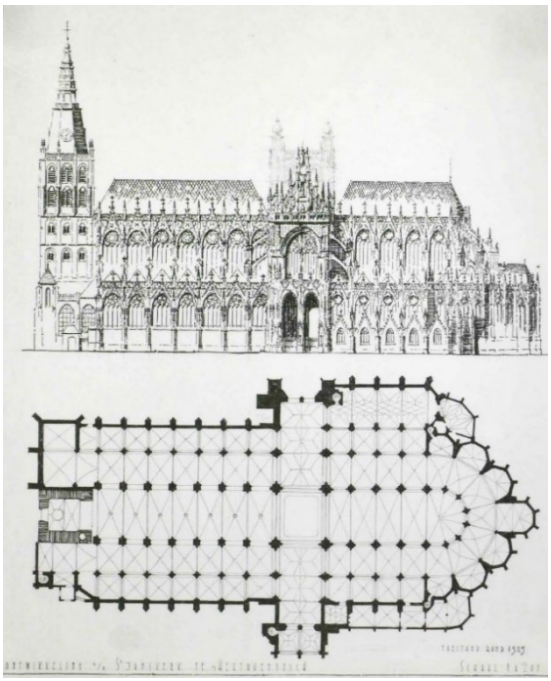

Figure 1: View of the southside of the church with floorplan (in 1525)[5].

For this thesis, an interview was conducted with Ronald Glaudemans, a building historian with a recently acquired doctorate in this field. As he has written many of the sources on the subject of this thesis, the interview gives an opportunity to get the information first hand and ask additional questions to fill gaps or clarify information from the sources. He agrees that the need for more architectural-historical research is great[6]. He noted in the interview, that historic and architectural researchers hardly ever collaborate on research projects, even though both fields are intertwined when it concerns the analysis of heritage buildings. With his research over the years he has tried to close the gap between aesthetic and structural architectural research, which is what this thesis aims to do as well.

This research asks the question: "Why were flying buttresses added in the 16th century redesign of St. John's Cathedral of Den Bosch?". Through analysing the building history of the St. John's Cathedral in Den Bosch, the aim is to study the overall added value of the flying buttress as a building element.

The St. John's Cathedral was chosen as the case study because it is one of the most noteworthy Gothic cathedrals in the Netherlands. It is a unique case because it once started out as a Roman-style church, built in the early 13th century, to which flying buttresses were added in a Gothic style redesign that was constructed from 1350 to 1530[7]. The motivation for the redesign of this cathedral was a significant growth of the surrounding

[2] Gabri van Tussenbroek, "Architectuur-en bouwhistorisch onderzoek ten behoeve van monumentenzorg." *Bulletin KNOB* (2006): 229-234.
[3] Ibid
[4] Ibid
[5] "View of the southside of the church with floorplan", n.d., 0014644, Imagery collection, Erfgoed 's-Hertogenbosch, Den Bosch. https://zoeken.erfgoedshertogenbosch.nl/detail.php?nav_id=170-1&index=0&imgid=21331951&id=15056948
[6] Sophia Benfield and Ronald A.H.M. Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[7] Erfgoed 's-Hertogenbosch. "De Geschiedenis Van De Sint-Jan in Den Bosch," n.d. https://www.erfgoedshertogenbosch.nl/verhalen/sint-janskathedraal.

community and the old roman church did not provide enough room for everyone[8].

The question is: why did the contractors decide to add the flying buttresses to St. John Cathedral in the redesign? Usually, cathedrals are built with the flying buttresses in the original design, while here they were added later on.

A number of books have been written about St. John's Cathedral during the 20th century [9] [10] [11], but it has barely been analysed as thoroughly as most contemporary buildings have, especially not structurally. Those books usually contain only a passing reference to the flying buttresses and its function. The most relevant and prominent research into St. John's Cathedral is that of the aforementioned Ronald Glaudemans, whose doctorate was obtained on the subject of this specific cathedral, in particular its building sculptures, including those on top of the flying buttresses [12]. His research has provided an overview of the available information through which relevant information for the focal point of this thesis – the flying buttress - can be found.

In the available literature, this cathedral has mostly been reviewed in full, treating it as a whole. This paper aims to focus on just one element, the flying buttress, and research its function and value for this cathedral into detail, by combining general research on the flying buttress with knowledge available on these specific elements of St. John's Cathedral.

The following chapter 2 describes the methods that were used to conduct the necessary research, both in terms of primary as secondary sources.

A literature review is conducted based on the main research question and its results will be presented in chapter 3. The main research question that this thesis means to answer is: "Why were flying buttresses added in the 16th century redesign of St. John's Cathedral of Den Bosch?"

Chapter 4 contains information on the framework, providing the necessary background knowledge on the flying buttress in general, St. John's Cathedral and other relevant concepts.

Chapter 5 delves into the research done on this subject and its results, while chapter 6 contains the conclusions drawn from the research.

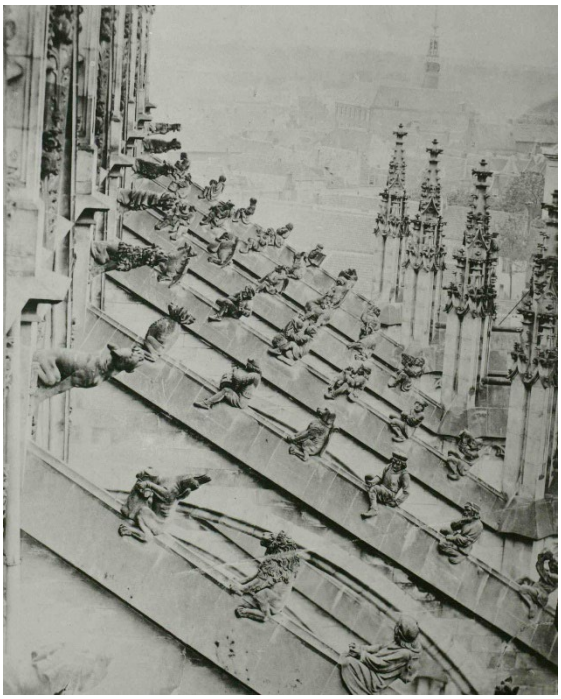

Figure 2: The flying buttresses on the northside of the nave, adorned with figurines[13].

[8] Cornelis F.X. Smits, *De Kathedraal van 's-Hertogenbosch*, Print. Brussel: Vromant & Co, 1907.
[9] Ibid.
[10] Jan Mosmans. *De Sint Janskerk te 's-Hertogenbosch*. Den Bosch: Drukkerij St Jan, 1931.
[11] Cornelis J.A.C Peeters. *De Sint Janskathedraal te 's-Hertogenbosch*. Den Haag: Staatsuitgeverij, 1985.
[12] Ronald A.H.M. Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550* (Zwolle: WBooks, 2017).
[13] "Flying buttresses figurines on the northside of the nave. City Hall in the background", 1889, 0006433, Imagery collection, Erfgoed 's-Hertogenbosch, Den Bosch. https://zoeken.erfgoedshertogenbosch.nl/detail.php?nav_id=172-1&index=4&imgid=21063785&id=14488309

2. Literature review: a study on flying buttresses

In relation to the research question, there are several areas that should be examined. Below a literature review has been conducted on each subject, to see which areas are sufficiently covered and which still require more research.

2.1. Structural functions of a flying buttress

The flying buttress has been around since at least the 12th century, so it is to be expected a lot has been written about them. The first to structurally dissect them was again Viollet-le-Duc, who explains the working through diagrams in his article "Construction"[14]. Since then, new research on this subject has applied recent technology to these building elements to calculate the structural forces in detail.

Examples of this can be found in several articles by authors Albert Samper and Rodrigo Martín-Sáiz (among others) [15] [16]. Nikolinakou[17] et al. have written a useful article in which different characteristics of flying buttresses are determined and how they influence effectivity, sometimes related to the point of collapse of a flying buttress. Another article that analysis the structure by looking at the collapse of flying buttresses was written by Verstrynge et al.[18], though it is a more in depth case study about two specific churches. Churches are usually smaller than cathedrals, so its relevance might be less than other articles about cathedrals specifically.

Some articles go really deep into technical details and calculations, like the one written by Quintas[19], but this kind of analysis is not relevant for this thesis and is full of jargon, which makes it difficult to read.

Most articles about flying buttresses take a case study to analyse, reconstruct and sometimes calculate. Some case studies used are: Amiens Cathedral[20], Canterbury Cathedral[21] and the Cathedral of Mallorca[22].

[14]Eugène-Emmanuel Viollet-le-Duc, *Rational Building; Being a Translation of the Article "Construction" in the Dictionnaire Raisonne´de l'architecture Française of Eugène Emmanuel Viollet-Le-Duc*, trans. George Martin Huss (New York: Macmillan, 1895).

[15] Albert Samper, Rodrigo Martín-Sáiz, and Blas Herrera, "On the Inclination of a Flying Buttress Arch," *Nexus Network Journal* 24, no. 4 (June 20, 2022): 897–911, https://doi.org/10.1007/s00004-022-00619-7.

[16] Albert Samper, Rodrigo Martín-Sáiz, and David Moreno-García, "Study on the Mechanical Capacity and Structural Relevance of a Flying Buttress through the Analysis of a Particular Case," *International Journal of Architectural Heritage* (July 24, 2023): 1–13, https://doi.org/10.1080/15583058.2023.2240268.

[17] Maria-Katerina Nikolinakou, Andrew J. Tallon, and John A. Ochsendorf, "Structure and Form of Early Gothic Flying Buttresses," *Revue Européenne de Génie Civil* 9, no. 9–10 (November 2005): 1191–1217, https://doi.org/10.1080/17747120.2005.9692807.

[18]E. Verstrynge, L. Schueremans, and P. Smars, "Controlled Intervention: Monitoring the Dismantlement and Reconstruction of the Flying Buttresses of Two Gothic Churches," *International Journal of Architectural Heritage* 6, no. 6 (November 2012): 689–708, https://doi.org/10.1080/15583058.2011.605201.

[19]V. Quintas, "Structural Analysis of Flying Buttresses," *European Journal of Environmental and Civil Engineering* 21, no. 4 (February 5, 2016): 471–507, https://doi.org/10.1080/19648189.2015.1131201.

[20] Robert Bork, Robert Mark, and Stephen Murray, "The Openwork Flying Buttresses of Amiens Cathedral: 'Postmodern Gothic' and the Limits of Structural Rationalism," *Journal of the Society of Architectural Historians* 56, no. 4 (December 1, 1997): 478–93, https://doi.org/10.2307/991315.

[21] Georgios Karanikoloudis et al., "Lessons from Structural Analysis of a Great Gothic Cathedral: Canterbury Cathedral as a Case Study," *International Journal of Architectural Heritage* 15, no. 12 (February 17, 2020): 1765–94, https://doi.org/10.1080/15583058.2020.1723736.

[22]Paula Fuentes, "Mechanics of Flying Buttresses: The Case of the Cathedral of Mallorca," *Journal of Mechanics of Materials and Structures* 13, no. 5 (December 31, 2018): 617–30, https://doi.org/10.2140/jomms.2018.13.617.

2.2. The flying buttress within the Gothic style

The flying buttress is a key element in the Gothic architectural style that originated in the 12th century. Besides its structural function it seems to have acquired an aesthetic, stylistic function, with it being a clearly recognisable element to identify gothic cathedrals with. Hutterer has written an article about the ornamentation of flying buttresses, by using the cathedral of Chartres as a case study[23]. Not many more specific articles can be found about the aesthetic value of the flying buttress, the information is usually structural or generally about the Gothic style.

An interesting source about the building process of gothic cathedrals is a book by Macaulay and Janse[24], it describes the building process of a fictional cathedral, to show how they were built in the past, with great detail. Though the cathedral described is not real, the methods in the illustrated book are real and based on archival research into the building process of other cathedrals. The fictional narrative does probably exclude it from use as a scientific source.

There are also some sources to be found about the specific Gothic movement in Brabant, the Dutch province where the St. John stands, which helps determine the most important influences[25].

2.3. The flying buttresses of St. John's Cathedral

Specific to the Saint John cathedral, little research has been specific to the buttresses. Many of the found texts are about the whole cathedral, like the works by Smits[26], Mosmans[27] and Peeters[28]. All three describe the cathedral and its building process in detail. Some of the conclusions drawn in al three books are not completely accurate, according to Glaudemans[29], who has conducted the most recent research on the St. John Cathedral.

The knowledge gap can be found in the specific research into the reason the flying buttresses were added to the redesign of the St. John.

2.4. Conclusion

It has become apparent from this literature review that the origin of the flying buttress has been sufficiently covered in existing research, as have the structural workings of said element. The knowledge gap lies in the analysis of the flying buttresses in the specified cathedral of St. John in Den Bosch.

There have been many descriptions of the flying buttresses, but hardly any in-depth analysis of the element. It is always reviewed as a part of the whole cathedral. The most specific statement about the addition of the flying buttresses has been done in the book by Glaudemans[30]. Other books about the cathedral[31] [32] [33] spend barely a couple of sentences on the subject and do not fully elaborate on the evidence for their statements. This is where more research is necessary and can hopefully shed some light on all facets of the function of the flying buttresses.

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[23] Maile Sophia Hutterer. "Lofty Sculpture: Flying Buttress Decoration and Ecclesiastical Authority." *Gesta 54*, no. 2 (2015): 195–218. https://doi.org/10.1086/681954.

[24] David Macaulay and H Janse. *De Kathedraal : Het Verhaal Van De Bouw*. Amsterdam: Ploegsma, 1974.

[25] Adrianus Koldewij. "De Brabantse Leeuw Sluimert (1356-1430): De Ontwikkeling van de Gotische Kunsten." Pdf. In *Geschiedenis van Brabant, van Het Hertogdom Tot Heden,* edited by Raymond van Uytven and Jan van Oudheusden, 197–211. (Zwolle : Waanders, 2004). https://repository.ubn.ru.nl/bitstream/handle/2066/94328/338338.pdf.

[26] Smits, *De Kathedraal van 's-Hertogenbosch*.

[27] Mosmans, *De Sint Janskerk te 's-Hertogenbosch*.

[28] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*.

[29] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550.*

[30] Ibid

[31] Smits, *De Kathedraal van 's-Hertogenbosch*.

[32] Mosmans, *De Sint Janskerk te 's-Hertogenbosch*.

[33] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*.

3. Methodology

Essential for this thesis are the primary sources, especially because research into this subject is already scarce. To obtain these primary resources, four starting points are identified. The first is the Cathedral itself, located in Den Bosch. A site visit provides insight into the scale of the cathedral and photographs will be taken for later analysis and comparison. The photos can be found in Appendix 2.

Secondly, there used to be an accompanying museum close to the cathedral, called 'De Bouwloods' (*translation: 'the building shed'*), which holds discarded or replaced ornaments from the flying buttresses and other construction materials, including a scaled model of the whole cathedral. However, during the site visit, it has become apparent that the museum has closed down and the items are no longer open for viewing to the public. Most of the items have been documented with images and put in the online image library of the Den Bosch archive, so they can be viewed there. The model has been placed on display in the cathedral instead. A photo taken of the model are also in Appendix 2.

The online repository of the archive is the third starting point for primary resources, because most of the archive materials have been digitalised and made available for downloading, so searching for materials is easy and accessible. Unfortunately, it turns out that most of the original documents about the cathedral were lost – or not kept in the first place by the builders, except for one receipt for materials used for the flying buttresses.

In the archive there are, however, some analytic drawings available made by scholars at later dates that might help in the analysis of the flying buttresses.

The fourth starting point is an interview with Ronald Glaudemans, building historian with both historic and architectural expertise on St. John's Cathedral. He has done the most extensive research into the cathedral and was present on-site for archaeological research while the second restoration of St John's Cathedral was going on from 1999 -2010. He also works closely with the Den Bosch heritage department and was promoted on the subject of the St Jan Cathedral. An interview with him might provide his knowledge on the flying buttresses. The notes that were taken during the interview, which was conducted on-site at the Den Bosch archive, can be found in Appendix 1.

4. Historic background

4.1. Clarification of terms

A cathedral contains many other elements beside the flying buttress, which together make up the whole structure and embellishment of a cathedral. To ensure full understanding of the case study and conclusions to follow it is necessary to introduce the different parts that make up the building. Following is a clarifying diagram of the appropriate names and locations of these elements. The images used to point out the various elements are a plan and section of the St John Cathedral of Den Bosch, which is also the main subject of this thesis.

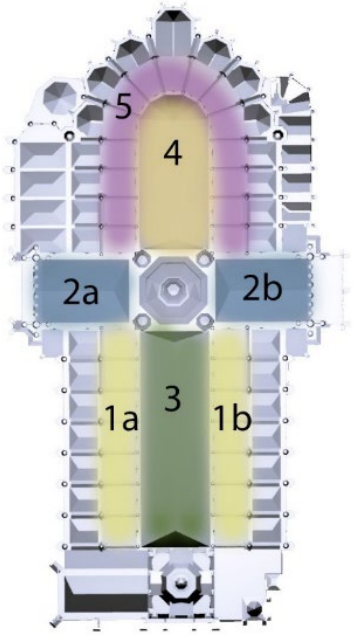

Figure 3: Various numbered areas within a cathedral[34]

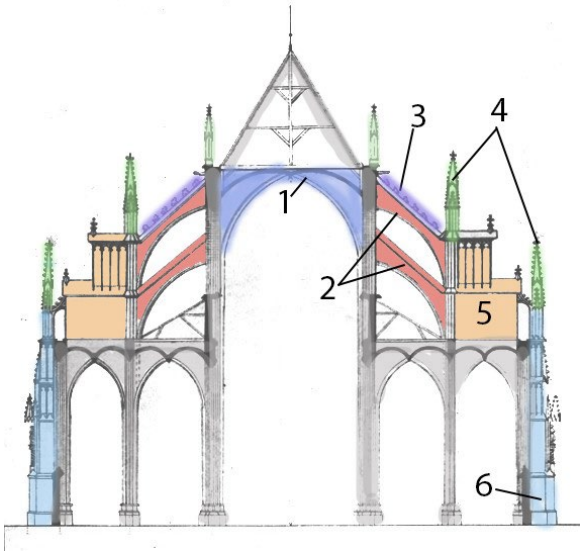

Figure 4: Various numbered elements of a cathedral[35]

Floorplan:

1. Double side aisles
    a. North
    b. South
2. Transept
    a. North
    b. South
3. Nave
4. Choir
5. Ambulatory

Section:

1. Vault (inner part of roof construction)
2. Flying buttress/ flyer
3. Ornaments/figurines
4. Pinnacle
5. Flyer chair
6. Buttress (regular)

[34] Author, 2024.

[35] Adaptation by the author (2024) of: "Doorsnede over de breedte van de St. Jans-Kerk te 's-Hertogenbosch", 1864, 0004561, Imagery collection, Erfgoed 's-Hertogenbosch, https://zoeken.erfgoedshertogenbosch.nl/zoeken/groep=Beeldmateriaal/Vrij_zoeken=doorsnede/Vervaardiger=Hezenmans%2C%20L.C./aantalpp=14/?nav_id=167-0.

4.2. The first flying buttresses

According to multiple sources[36] [37] [38] the flying buttress was first developed as a structural element in architecture while building the nave of the Notre Dame in Paris at the end of the 12th century. However, over the years that statement has been questioned by many scholars.

Research by Charles Stewart presents evidence that the flying buttress already existed in older cultures, like 4th century Byzantine Cyprus[39]. Stewart argues that placing the origin of the flying buttress with 12th century France is a typical show of western privilege. However, the use of those flying buttresses is in a slightly different context than cathedral building, as the buttresses are not so much flying as serving a purpose at ground level (figure 5). In the conducted interview, Ronald Glaudemans also confirmed the existence of earlier flying buttresses, mainly in Jugoslavia and Italy, that took the form of perforated regular buttresses, as a primitive version of what we now know as a flying buttress[41]. Research on this subject is unfortunately very scarce and hard to find.

Figure 5: Early flying buttresses in Salamis-Constantia, Byzantine Cyprus[40]

If not the first flying buttresses in general, can the flyers of the Notre Dame be named the first in cathedral building? Results are inconclusive. The flying buttresses are said to have been built just before 1180, but Mark questions the original dating of the flying buttresses of the Notre Dame, because they were replaced somewhere during the 13th century, so an accurate date on the construction is difficult to define[42]. John James also presents conflicting evidence that the Notre Dame might not be the first to have flying buttresses, but other similar cathedrals from the same time-period may be the first[43], but the margin is a small one.

Jean Bony names the flyers of Saint-Germain de Prés and Saint-Leu D'Esseret as possible places where the flying buttress originated, but also notes that all these churches were built around the same time in close proximity to the Notre Dame in Paris, which could still mean that is where the element originated[44]. Similarly, the flyers from Canterbury Cathedral have the same dating as the Notre Dame, but were built under direction of a French building master,

[36] Clark and Mark, "The First Flying Buttresses: A New Reconstruction of the Nave of Notre-Dame De Paris."

[37] Jean Bony, *French Gothic Architecture of the Twelfth and Thirteenth Centuries* (Berkeley: University of California Press, 1985).

[38] Austin Ruddle. "Examining the Impact of Flying Buttresses and Other Innovative Strategies in High Gothic Cathedral Design." *Intaglio* 2 (2020): 24–34. https://hcommons.org/deposits/item/hc:49917

[39] Charles Anthony Stewart. "Flying Buttresses & Pointed Arches in Byzantine Cyprus," in

[40] "Grand Baths at Salamis-Constantina. V View of north wall's flying buttresses, towards the west", 2016, *in Masons At Work*, ed. by R. Ousterhout, L. Haselburger, and R. Holod. University of Pennsylvania, 2.

[41] Sophia Benfield and Ronald A.H.M. Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.

[42] Robert Mark, "Robert Willis, Viollet-Le-Duc and the Structural Approach to Gothic Architecture," essay, in *The Engineering of Medieval Cathedrals*, ed. Lynn T Courtenay, 1st ed., vol. 1, Studies in the History of Civil Engineering (Routledge, 1997), 1–14

[43] John James, "Evidence for Flying Buttresses Before 1180," *Journal of the Society of Architectural Historians* 51, no. 3 (September 1992): 261–87, https://doi.org/10.2307/990687.

[44] Bony, *French Gothic Architecture of the Twelfth and Thirteenth Centuries*

which could explain this overlap in new construction elements[45].

4.3. Development of the flying buttress in Gothic cathedrals

Whichever cathedral was the first, the building process of Notre Dame in Paris tells us the most about why flying buttresses were added. The 19th century structural scholar Eugène-Emmanuel Viollet-le-Duc gives a description of the development process[46]. His work is the most referenced concerning the flying buttress as he was the first to examine the construction of Gothic cathedrals. Viollet-le-Duc states that the flying buttress was developed solely as a structural enhancer of the roof support, when the initial structure proved insufficient[47]. It was an act of desperation, which later culminated in an iconic element associated with the Gothic style.

During the development of the Roman style to the Romanesque style, that preceded the Gothic style, a new vault roof system was devised that put more outward pressure on the piers holding it up and fissures in the construction were soon observed[49]. Some were so severe they caused the vault construction to collapse (figure 6).

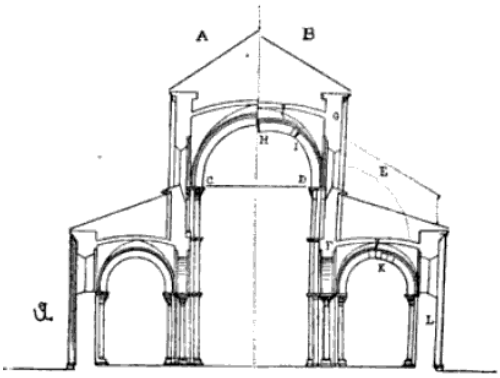

Figure 6: Before (A) and after (B) force-induced deformation occurred at the church of Vezelay[48]

The first attempts at flying buttresses were often not very effective, and the early ones had to be rebuilt or revised later on to make them fully functional[50]. It was an experimental development, that relied both on the structural expertise of the master builders in combination with trial and error. This was also the case with the building of the flyers of the Notre Dame in Paris, which were less effective during the initial building process until they were amended[51].

4.4. Various practical functions of flying buttresses

4.4.1. Structural function

The flying buttress was used to significantly increase the height of the naves and choirs of cathedrals, while keeping the walls as thin as possible[52] [53]. They also enabled builders to add larger windows to the walls in-between where the flyers and buttresses were connected, because these wall segments were now less needed for support[54]. All forces were diverted directly to the (flying) buttresses. This was done to let maximum daylight into the central spaces of the building[55]. Thinner walls meant less mass to support the roofing vaults, which were usually made of stone and were very heavy.

The Gothic vault-ceiling structures culminate in both horizontal and vertical forces that affect

[45] Mark, "Robert Willis, Viollet-Le-Duc and the Structural Approach to Gothic Architecture."
[46]Viollet-le-Duc, *Rational Building; Being a Translation of the Article "Construction" in the Dictionnaire Raisonne´de l'architecture Française of Eugène Emmanuel Viollet-Le-Duc*
[47] Ibid
[48] "Figure 15", Ibid, Lvi.
[49] Ibid
[50] Ibid
[51] Ruddle, "Examining the Impact of Flying Buttresses and Other Innovative Strategies in High Gothic Cathedral Design."
[52] Bony, *French Gothic Architecture of the Twelfth and Thirteenth Centuries*
[53] Bork, Mark, and Murray, "The Openwork Flying Buttresses of Amiens Cathedral: 'Postmodern Gothic' and the Limits of Structural Rationalism,"
[54] Clark and Mark, "The First Flying Buttresses: A New Reconstruction of the Nave of Notre-Dame De Paris."
[55] Ibid.

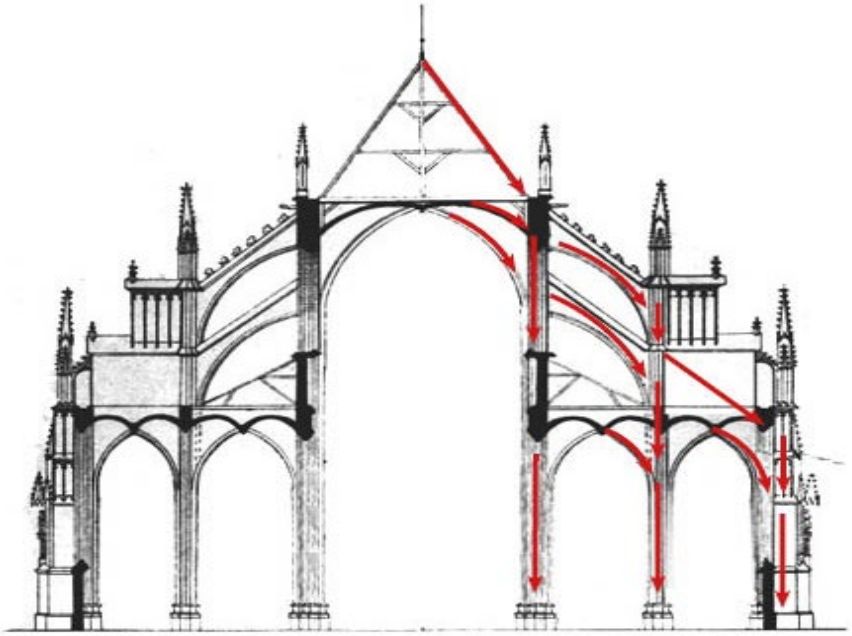

Figure 7: The way down of the forces from the roof down to the ground[58]

the walls[56]. The vertical forces are easily diverted to the ground through the

vertical walls, specifically the buttresses that are part of the wall-construction, but the horizontal forces present a problem. Without the right support, this horizontal compression could elicit pull (traction) forces on the stone construction, which is not made for these forces and could crack or crumble. To divert the horizontal forces to the ground, stone arches can help bend them into vertical forces[57]. Flying buttresses fulfil this part in the construction by directing them to the pier buttresses on the outer edge of the cathedral. Through those, the forces are directed to the foundation. Figure 7 shows the flow of the forces from the roof down to the ground.

Some cathedrals would have not one but two or more tiers of flying buttresses. When double-tiered flying buttresses are present on a cathedral, the two fulfil different purposes. It is the lower one that actually deals with the thrust of the roof vaults, while the upper flyer stabilises the wall and neutralises wind forces[59].

4.4.2. During construction

The flying buttress fulfilled such a specific duty to keep the roof from collapsing, that it was necessary to build them as soon as possible after the roof was built. Sometimes during the constructive phase, makeshift flyers were made – usually from steel rods – and placed temporarily to provide support until the actual flying buttresses were in place[60]. When the building of the real flying buttresses was left too long, the roof vault could end up collapsing, which was the case with the Dom church in Utrecht[61].

[56] Ibid
[57] Ibid
[58] Adaptation by the author (2024) of: "Doorsnede over de breedte van de St. Jans-Kerk te 's-Hertogenbosch", 1864, 0004561, Imagery collection, Erfgoed 's-Hertogenbosch,
[59] Bork, Mark and Murray, "The Openwork Flying Buttresses of Amiens Cathedral: 'Postmodern Gothic' and the Limits of Structural Rationalism," 478.
[60] Sophia Benfield and Ronald A.H.M. Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[61] Ibid

4.4.3. Water drainage

In some cathedrals, like the Cathedral of Amiens, the flying buttresses were designed to help drain water from the roof, like a gutter, and guide it away from the walls. Grooves were cut into the top stones covering the flyers[62].

This does mean, however, that the stones of the flyer are eroded by the water flowing through and the material of the flyer deteriorates quicker. This caused builders in the Renaissance time (following the Gothic period) to hide the flying buttresses in the roof construction and no longer expose them to the elements outside[63].

4.5. Architectural significance: Gothic style

The Gothic style developed in Europe in the Late Middle Ages, with the apex of its influence located in France, where numerous Gothic cathedrals were built. It was in France that the flying buttress was developed and added to the list of elements representing the Gothic style. It initially had a structural purpose, but it became so iconic that it was sometimes added without serving a purpose, for example in some English cathedrals. These cathedrals were usually built with more mass than those of French origin – due to an incentive to be economical with materials in France – and flying buttresses were not always necessary, but were added only to place the building within the Gothic style[64].

In The Netherlands Gothic architecture flourished in the province of Brabant, in the more southern regions. There the Gothic style had come over from France via the border regions and what is now Belgium through French building masters that travelled across Europe[65]. The style was therefore mostly related to the French Gothic, though a little less grand. Some important elements of the Brabants Gothic were, among others, cross vaults (though less complicated than many French cathedral had), eight-sided pilar pedestals, embellished triforia (a kind of three-part window), ornamental statues with great detailing – only a little less neat than the French equivalents – and of course the flying buttress[66]. The Gothic style worked from a skeleton of columns and arches that form the main structure[67]. The flying buttress is a good example of this skeletal structure. The golden Ratio was also important in design of elements and general measurements[68].

The flying buttress is the most recognisable element from the Gothic style. Reverend Xavier Smits – a certified historian from Brabant – counts the flying buttress as being part of the essence of Gothic architecture. It was the "one thing keeping the immensely high vaulted ceilings upright"[69].

The Brabant-segment of the Gothic style eventually culminated in an architectural school devoted to the style in the beginning of the 15th century. This building style aimed to outbuild and outlive similar architecture in the North of the Netherlands and the builders of the Brabant Gothic kept to the stylistic tradition until well into the 16th century, when around them the Renaissance was already changing the architecture[70].

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[62] Bork, Mark and Murray, "The Openwork Flying Buttresses of Amiens Cathedral: 'Postmodern Gothic' and the Limits of Structural Rationalism," 478.
[63] Smits, *De Kathedraal van 's-Hertogenbosch, 117.*
[64] Mark, "Robert Willis, Viollet-Le-Duc and the Structural Approach to Gothic Architecture."
[65] Smits, *De Kathedraal van 's-Hertogenbosch, 56.*
[66] Ibid, 56 & 96.
[67] Wim van de Ven, *Sint Jan, een Openbaring: Een Verrassende Kijk op de Kathedraal*, ed. Jo van Eysden-Wolters and Ben Spekman, 1st ed. (Den Bosch: Werkgroep Sint Jan, 1985).
[68] Jan de Jong, *Sint Jan, een Openbaring: Een Verrassende Kijk op de Kathedraal*, ed. Jo van Eysden-Wolters and Ben Spekman, 1st ed. (Den Bosch, Netherlands: Werkgroep Sint Jan, 1985).
[69] Ibid, 117.
[70] Ibid, 110.

5. Case study: Research into the purpose of the flying buttresses of the St John Cathedral of Den Bosch

5.1. Description of the flying buttresses of the St John Cathedral

The St John Cathedral of Den Bosch has flying buttresses against the nave of the cathedral, against the choir and against the sides of the two transepts. Figure 8 shows a diagram of all flyers. The St John has double-tiered flying buttresses (Figure 9), which means each number refers to a pair of two flyers on top of each other. This makes the total of the flyers on the cathedral: 33x 2 = 66 flyers.

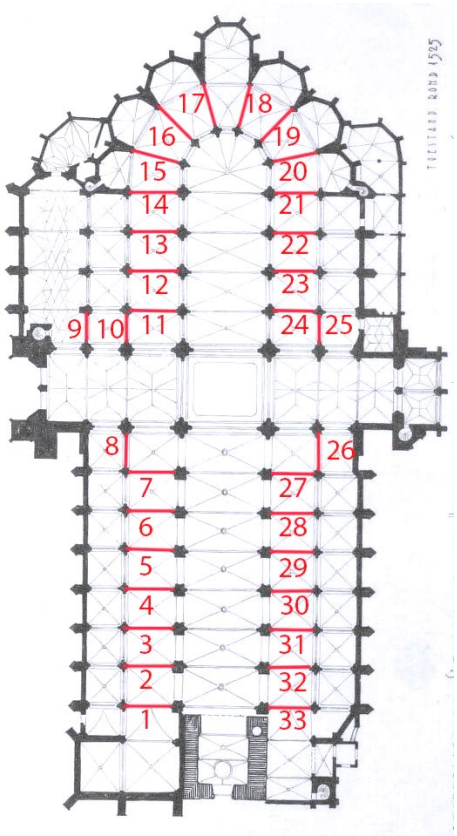

Figure 8: Locations of all flying buttress pairs in the St John Cathedral[71]

Figure 9 shows the dimensions of the flying buttresses of the cathedral choir. The measurements are in meters and should probably be given a little margin; The measurements are taken from a drawing by Peeters in his book about the cathedral[72], which cannot guarantee complete accuracy. The lowest point of the bottom flyer starts 14,9 meters above ground level. The flyers sustain an inner vault height of 27,6 meters in the choir[73]. The blue digit preceded by an 'R' means the radius of the arch.

Figure 10 shows the dimensions of the flying buttresses of the nave of the cathedral, also based on a drawing by Peeters[74]. The nave flyers have a less steep inclination than the choir flyers. The lower flyer of the nave starts at 14,7 meters above ground level. The flyers sustain an inner vault height of 28,3 meters in the nave[75].

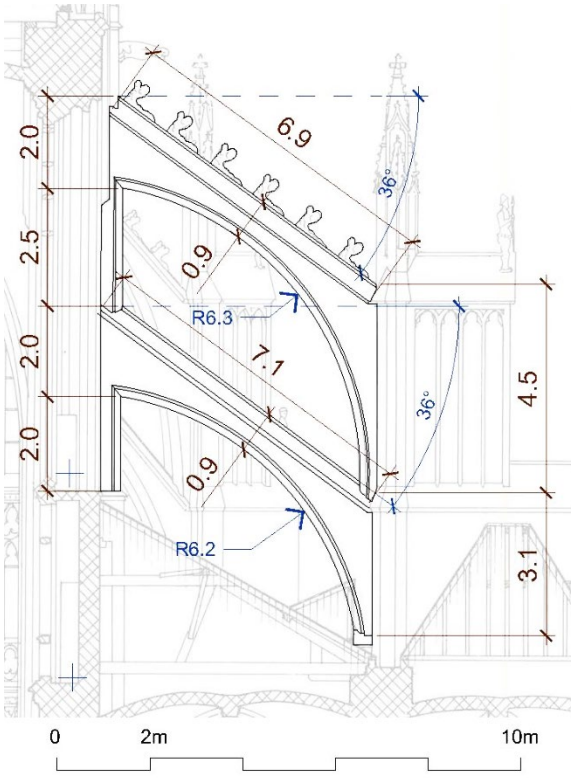

Figure 9: Flying buttress pairs of the choir of the St John Cathedral[76]

[71] Author, 2024.
[72] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, appendix 5.
[73] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch, 181.*
[74] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, appendix 3.
[75] Ibid, 181.
[76] Author, 2024

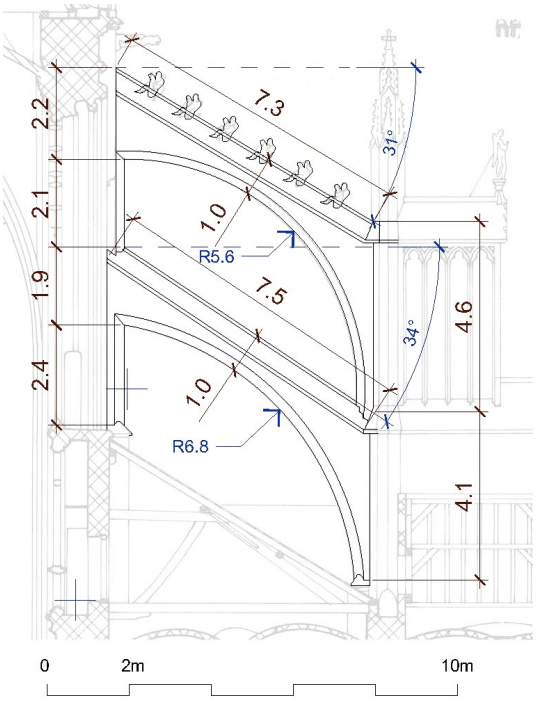

Figure 10: Flying buttress pairs of the nave of the St John Cathedral[77]

5.1.1. Materials

The use of materials varies in the St John cathedral. The core of the flying buttresses was made of brick and then hidden behind natural stone like tuff, limestone or sandstone[78]. The choice of natural stone depended on the trading possibilities with stone quarries in the area, often in Germany or Belgium[79].

Only one document was retrieved from the time the cathedral was built. It is dated from 1478 and contains an order for fourteen stone components used to build the seven double flying buttresses on the Northside of the nave[80], which means the stone in question was sandstone[81]. Figure 11 shows the original document as in the archival collection of Erfgoed 'S-Hertogenbosch.

Glaudemans doubts this analysis and states the order is misinterpreted and. It is not about the flying buttresses but another kind of arch. The order is too soon for the building of the nave and the figurines are not mentioned, which they should have to get enough material[82].

A more porous, volcanic stone 'tuff' was used for the flying buttresses on the southside of the nave and the ambulatory and choir[83]. In a big restoration at the end of the 19th century, the softer tuff stone had sustained more weathering than the sandstone so they were completely replaced[84].

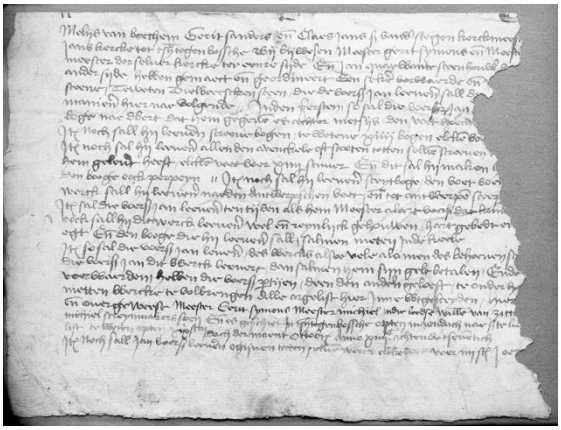

Figure 11: Receipt for building materials from 1478 possibly mentioning the flying buttresses[85]

[77] Author, 2024.
[78] Smits, *De Kathedraal van 's-Hertogenbosch,* 141.
[79] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[80] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*.
[81] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[82] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 341.*
[83] Ibid
[84] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 76.
[85] "Contract tussen de kerkfabriek van Sint Jan en Jan Quaywante over de levering van steen.", 1487, 0013091, Imagery collection, Erfgoed 's-Hertogenbosch, Den Bosch. https://zoeken.erfgoedshertogenbosch.nl/detail.php?nav_id=152-1&id=14950341&index=0

5.2. Structural significance flying buttress in the St. John Cathedral

5.2.1. From the Roman cathedral to the Gothic cathedral

Before the immense Gothic cathedral was built, a Roman style church stood in its place. Figure 12 shows an impression of this church, with the ghost of the new Gothic tower hovering over it. Roman architecture uses the square as a basal shape, vertically oriented[86]. This is clearly visible in the old church, with its clean straight lines and square tower, that fits about three times in the length of the nave. Gothic architecture uses the rib vault, which is more triangularly shaped, also in its ornaments.

Figure 12: Impression of the Roman version of the St John Cathedral in Den Bosch[87]

Ornaments are lacking in the Roman church and the windows are very small.

The decision to enlarge the original Roman church was made because it became too small for the growing community of the city Den Bosch[88]. A chapel was added in 1268 for that same reason, before the start of the new cathedral in 1280. Funds donated by pilgrims drawn to the church for Mary-devotion and a special statue of Mary that stood in the chapel, made the building of the second design possible[89]. This phenomenon was common in that time period; that the expanding of churches was linked to available funding.

In the new Gothic St John Cathedral the Choir was changed first. At the back of the church the roof was heightened significantly. According to Smits, the flying buttresses against the choir were added between 1419 and 1439, to make the increase of height possible of the choir roof and walls. The nave was also expanded from the then usual 3 aisles to 5 aisles[90] and the roof was heightened, like what had been done to the choir. The north side flyers of the nave were added somewhere after 1478[91]. According to Jan Mosmans, the whole cathedral ended up being 2/3 of a French cathedral in size[92]. The windows that were before very small were enlarged to let in more natural lighting. The flying buttresses made this possible, as described in paragraph 4.4.1.

5.2.2. Necessary proportion of buttresses to the structure

As described in paragraph 4.3, the flying buttress was used to enhance the construction of cathedrals so the walls could contain larger windows and be less massive. Peeters[93] speculated that the flying buttresses of the St. John Cathedral were not as functional as for

[86] Herman Teering, *Sint Jan, een Openbaring: Een Verrassende Kijk op de Kathedraal*, ed. Jo van Eysden-Wolters and Ben Spekman, 1st ed. (Den Bosch: Werkgroep Sint Jan, 1985).

[87] "De Romaans-Gothische toren, zoals deze aan de Romaanse kerk heeft gestaan, met verhoging met klokkenhuis en leien spits.", n.d., 0033850, Imagery collection, Erfgoed 's-Hertogenbosch, Den Bosch. Accessible on 1 march, 2024, at: https://zoeken.erfgoedshertogenbosch.nl/detail.php?nav_id=148-1&index=0&imgid=21102981&id=14571124

[88] Smits, *De Kathedraal van 's-Hertogenbosch,* 15.

[89] Ibid, 26-27.

[90] Ibid, 112.

[91] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 76.

[92] Mosmans, *De Sint Janskerk te 's-Hertogenbosch*, 228.

[93] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*.

example in the Notre Dame in Paris, because the cathedral was lacking in height in comparison. This would suggest at least the second row of the flyers were added for mostly aesthetic reasons, to fit within the Gothic style. This was not uncommon, for example in England many churches that were massive enough on their own received additional flyers to adhere to the rules of the Gothic[94]. However, this speculation is refuted by Glaudemans who clearly attributes the holding up of the heavy stone roof to the flying buttresses [95]. According to his research, the mass of the flying buttresses was conceived by the building masters according to what was necessary[96]. Even the ornaments were part of the mass that was meant to counteract the outward thrust provided by the roof construction. The main reason for this elaborate bracing construction was the stone vaults, which are heavier than the in the Netherlands more commonly used wooden roof constructions[97]. A heavier roof produces more outward forces on the wall construction and requires more counterweight.

Smits takes an opposing view of the builders' expertise: he states that in the time that the cathedral was built it was not possible to determine the exact amount of weight from the roof construction[98]. They had to guess at least partly – there were no electronic devices that could help with these calculations – and that to be sure the cathedrals construction was safe, the building master added the second layer of flyers on top of the first. Peeters agrees with him that the second layer of flyers is probably structurally unnecessary[99]. According to Peeters, the flying buttresses along the nave of the cathedral were removed during restoration somewhere in the 1870's without a temporary bracing to improve lateral stability. It did not result in damage to the cathedral, so he concludes that the support of these flyers is not crucial at least[100].

Double flyers are not seen anywhere else in The Netherlands, even Glaudemans calls their addition to the St John "unusual"[101]. When touching on the reason for adding them, Smits draws a parallel with the French cathedral of Amiens and the one of Cologne (Germany), which the St John resembles in more ways than one[102]. He thinks they modelled the St John after one of these cathedrals and that the double flyers were added because of that. Whether this inspiration would have been taken for constructive or stylistic reasons, we cannot know for sure.

The flyers of the two transepts show signs of amendments at the supporting flyer chair. The size of the chair and consecutive buttress was increased to counteract the fact they used less flying buttresses than required[103]. On the westside there is only one pair for the whole wall, which Glaudemans deems too little.

5.2.2.1. Comparison with the Dom Church of Utrecht

To discover a new perspective on the much debated proportion and necessity of the, a comparison is made with the Dom Church in Utrecht, a similar sized cathedral to the St John of Den Bosch. The St John has the double layer of flyers, but the Dom only has a single layer of flyers. Figure 13 shows the two cathedrals placed next to each other, with their flying buttresses highlighted. The vault height of the Dom is actually more than the St John, but still the Dom has less flyers. From this we can conclude that one layer of flying buttresses might have sufficed for the construction of the

[94] Mark, "Robert Willis, Viollet-Le-Duc and the Structural Approach to Gothic Architecture."
[95] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[96] Ibid.
[97] Smits, *De Kathedraal van 's-Hertogenbosch,* 115.
[98] Ibid.
[99] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 387.
[100] Ibid, 74.
[101] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 175.*
[102] Smits, *De Kathedraal van 's-Hertogenbosch*, 117.
[103] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 213.*

St John. One difference between the dimensions of the flyers of both cathedrals is that the flyers of the Dom have a steeper inclination of 46%, compared to 36% of the St John flyers. According to Nikolinakou, Tallon, and Ochsendorf the higher the inclination, the more of the force load is directly transferred to the buttress below, which takes pressure off of the cathedrals wall.[104] The Dom flyer could therefore be more efficient than the St John flyer, but their similarity in shape and size makes that it is a small margin.

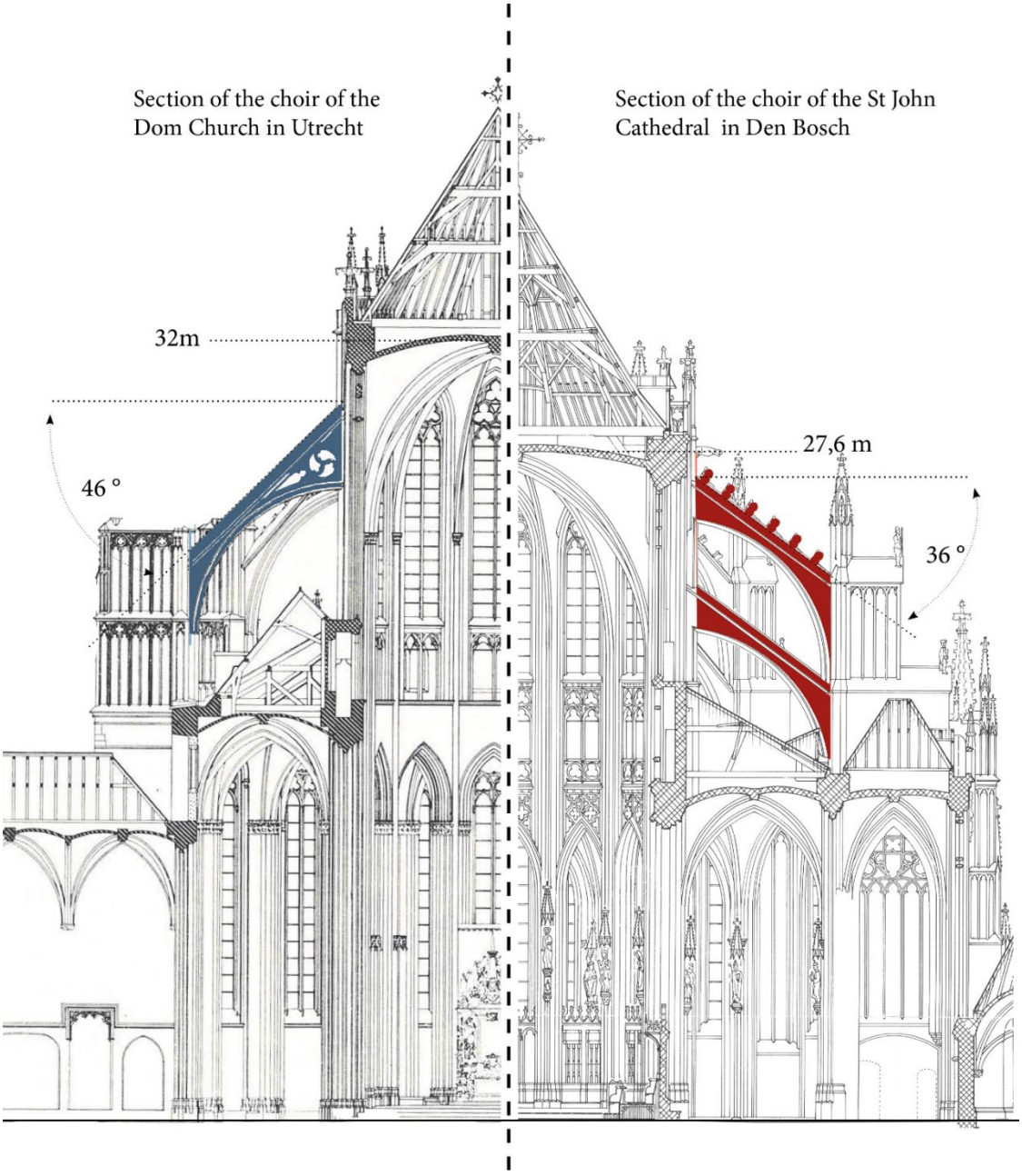

Figure 13: Comparison Dom Church Utrecht and St John Cathedral Den Bosch[105]

[104] Nikolinakou, Tallon, and Ochsendorf, "Structure and Form of Early Gothic Flying Buttresses,"

[105] Author, 2024. Adaptation of drawings by Peeters of St John Cathedral and the Dom Church of Utrecht.

5.2.3. During construction

Between 1370 and 1385 the bottom half of the new choir was built, including the flyer chairs and only the starting point of the flying buttresses. Only after this was finished did they proceeded with building the upper choir[106]. The flying buttresses were added simultaneously with each part of the wall the were meant to support[107]. This was the safest way for the upper choir to be built, as the chances of collapse were very small. It means no temporary bracing was needed during construction, which is sometimes the case. The original flyers fulfilled this purpose. The nave was built in a similar way, also requiring no temporary bracing[108].

5.2.4. Ornamentation

The St John Cathedral also has statues placed on the top of the buttresses supporting the flying buttresses. These seem to only fulfil an ornamental role, but their weight does in fact contribute to the counteracting of the outward forces coming from the roof vault[109]. This is also the case for the little figurines on top of the flyers. While building the cathedral the weight of these ornaments was taken into account when determining how much mass was necessary to counteract the outward roof forces. Heavier ornamentation meant the flyers could be smaller, more delicate.

Glaudemans notes that the sculptures should definitely not be seen as separate from the construction, but as an integral part, as all sculptures are completely mortared into the constructive stone shell[110]. They were not just added later on for embellishment.

5.3. Architectural significance of the flying buttress in the St. John Cathedral

5.3.1. Style: 'Brabant's' Gothic

The St John is very obviously a Gothic style cathedral, with the distinctive arches, trifora and eight-sided columns. It relies heavily on the French section of the Gothic style, which was the main influence of Brabants Gothic[111]. Most elements are similar to French cathedrals like Amiens and Beauvais, especially the floorplan is close to that of Amiens[112]. Teering states the St John was probably modelled on this cathedral[113]. The contractors of the cathedral wanted to make a worthy cathedral for the growing city of Den Bosch and which is why they spared no resource or effort to liken the St John to the famous French cathedrals[114].

The flying buttresses are the most iconic Gothic element and the St John has no less than 66 of them. They contribute to lightening the heavy stone exterior of the cathedral. During that period churches and cathedral also represented the connection with God and the divine. The flying buttresses could be seen as a heavenly arch, giving a light, ephemeral quality to the cathedral, while it was built with heavy materials like stone and brick[115].

5.3.2. Decorative figurines and crockets on the flying buttresses

The top layer of flying buttresses of the nave and west-side of the transepts are adorned with 96 figurines, six on each flyer[116].

When the north transept was built, even before the nave, the top flying buttress on the westside was the first to receive what are now the iconic figurines that give the St John a

[106] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 174.*
[107] Ibid, 175.
[108] Ibid, 347.
[109] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[110] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 25.*
[111] Smits, *De Kathedraal van 's-Hertogenbosch, 56.*
[112] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 387.
[113] Teering, *Sint Jan: een Openbaring.: Een Verrassende Kijk op de Kathedraal*
[114] Smits, *De Kathedraal van 's-Hertogenbosch.*
[115] Teering, *Sint Jan: een Openbaring.: Een Verrassende Kijk op de Kathedraal*
[116] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 257.

special edge among all cathedrals[117]. These first figurines seem to have been placed just after 1440, at least 40 years before the flying buttresses were added to the nave[118]. This means the figurines were not just an afterthought, they were planned early on in the design, though there is a small chance they were added later to make the ornamentation fit with the surrounding flyers[119]. This cannot be traced due to replacement of the figures in the 19th century.

The upper flyers of the choir do not have decorative figurines, instead they have crockets on top[120] [121], a decorative gothic element that looks like a curled leaf[122]. This element is of French origin and is used most in rows, as they are on the flyers of St Johns Cathedral. Their shape is reminiscent of oak leaves[123].

The figurines have the same function as crockets, but have not been seen before on flying buttresses[124]. They were later seen on a small French church in Sézanne, and some on Westminster Abbey, but nowhere else[125].

Different theories about their meaning have been developed over time because hard evidence on their iconography is lacking. This is probably due to the low amount of literate people in the middle ages[126].

Peeters denied any real underlying message could be contributed to the figurines and that their form was left to the whims of the sculpture[127]. Smits does not agree. He talks of the origin of the characters in the 'popular culture' of that time, mainly knight-romance stories, fairytales and fables that the general public enjoyed[128]. Around that time they made a poor-mans bible in pictures to make it accessible for the usually illiterate public. The books were often added to, in the form of more profane images[129]. These images might have inspired some of the figurines.

Smits also offers the explanation of a church-like symbolism; the figures on the flyers represent the whole of humanity and the strange creatures that are mixed in represent the demons who present obstacles to humanity during their time on earth, a sort of demons, of you will[130]. Smit himself admits it is farfetched, but intriguing. Mosmans does agree with him lightly[131]. Glaudemans admits it is difficult to say for certain the message behind the figurines and agrees with Smits that it probably came from popular culture references that we no longer understand[132]. Some of the figurines can be identified or linked to stories, usually from the bible. Examples are Samson and the Three Kings and demonic creatures[133]. Some can be linked to virtues, like a bear eating honey meant gluttony[134]. Other, less identifiable figurines can be categorised as monsters, musicians, and disfigured people, that probably represented various illnesses people believed stemmed from demons[135].

5.3.3. New figurines: Restoration of the 19th century:

In 1855 the St John Cathedral was among the first restoration projects to be attempted in the Netherlands. There was no knowledge available on the subject of restoration, as no one had

[117] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 212.*
[118] Ibid
[119] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 359.*
[120] Ibid, 184.
[121] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 175.*
[122] Editors of Encyclopaedia. "crocket." Encyclopedia Britannica, July 20, 1998. https://www.britannica.com/technology/crocket.
[123] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 242.
[124] Ibid, 243.
[125] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[126] Ibid.
[127] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 240.
[128] Smits, *De Kathedraal van 's-Hertogenbosch,* 137.
[129] Ibid, 138.
[130] Ibid, 181.
[131] Mosmans, *De Sint Janskerk te 's-Hertogenbosch*, 303.
[132] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[133] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 374.*
[134] Ibid, 370.
[135] Ibid, 375.

attempted it before[136]. The supervisors looked to other similar building projects for guidelines, in this case the Cathedral of Keulen. However, that was not a restoration project, but still the initial construction that was being finished and this caused the restaurateurs to assume the only way to restore a building like the St John was to rebuild the parts that were in a dire state[137]. Some of the flying buttresses and the figurines on top were completely replaced during this process[138]. It was only later that they learned how to restore buildings while keeping the original construction and materials intact.

A lot of the figurines on top of the flyers were in bad shape, some unrecognisable, so many were replaced and the missing figurines were redesigned, based as much as possible on the original figures[139]. Hezemans was the main designer of these new ornamental figures. His drawings of them are shown in figure 14.

Figure 14: drawings by Hezemans[140]

5.4. Other functions of flying buttresses in the St. John Cathedral: rainwater drainage

In some Cathedrals flying buttresses have gutters to help with rainwater drainage[141], but this is not the case in the St John Cathedral. Though saddleback copings on top of the flying buttresses protect the element itself from rainwater[142], it does not possess any further drainage function. Figure 15 shows the flying buttresses of the nave of the St John, clearly they do not have gutter grooves, they would be obstructed by the figurines if they had. The flyers of the nave have more of a groove (Figure 16), but it does not seem a convincing rainwater drainage gutter, compared to the one from Amiens, which is positioned on top of the flyer and has a gargoyle directly connected to it that pours in the rainwater (Figure 17). The gargoyles of the St John are also visible in figures 15 and 16, and they are clearly not connected to a gutter system in the flying buttresses.

Figure 15: St John Cathedral, nave flyers[143].

[136] Benfield and Glaudemans, Flying buttresses of the St John Cathedral, personal, February 29, 2024.
[137] Ibid
[138] Ibid
[139] Glaudemans, *De Sint-Jan Te 's-Hertogenbosch: Bouwgeschiedenis En Bouwsculptuur 1250-1550, 363.*
[140] "Luchtboogfiguren uit het schetsboek van L. Hezenmans.", n.d., 0023099, Imagery collection, Erfgoed 's-Hertogenbosch, Den Bosch. https://zoeken.erfgoedshertogenbosch.nl/detail.php?nav_id=157-1&index=1&imgid=21308411&id=15006632
[141] Bork, Mark and Murray, "The Openwork Flying Buttresses of Amiens Cathedral: 'Postmodern Gothic' and the Limits of Structural Rationalism," 478.
[142] Peeters, *De Sint Janskathedraal te 's-Hertogenbosch*, 184.
[143] Author, 2024.

Figure 16: St John cathedral, choir flyers[144].

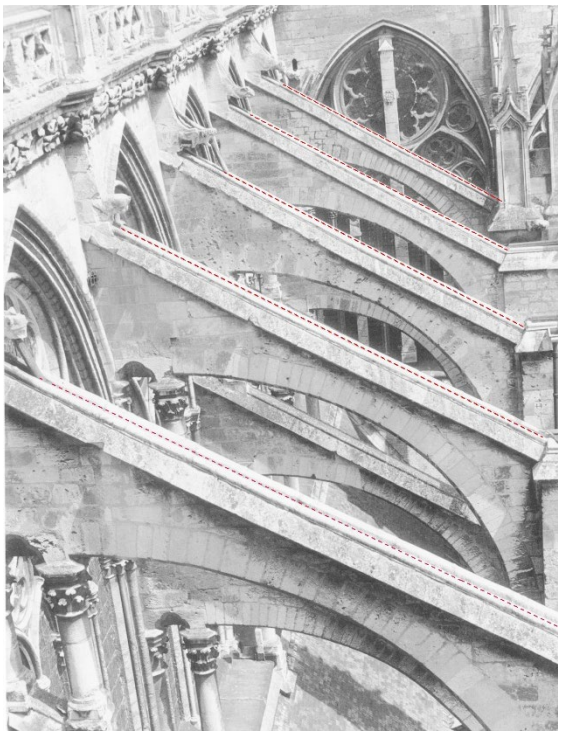

Figure 17: Amiens cathedral, nave flyers[145].

[144] Author, 2024.

[145] Adaptation of image from: Bork, Mark and Murray, "The Openwork Flying Buttresses of Amiens Cathedral: 'Postmodern Gothic' and the Limits of Structural Rationalism," 479.

6. Conclusion

This thesis has explored many different possibilities for the added value that the flying buttresses of the St John provide for this particular cathedral. From the different sources about the St John Cathedral it has become apparent that there is no real doubt whether the flying buttresses hold a structural function and are necessary to counteract the thrust forces from the heavy, stone roofs. Even the various ornaments placed on top contribute to the counterweight the flyers provide for the thrust forces. There is, however, a debate about the proportionality of the flying buttresses, about how big of a contribution they really make. Questions like: *could they have been smaller?* or: *Is the second row really necessary?* are raised by several sources.

Especially the second point about the second row of flyers is worth reviewing. According to Bork et al. the second layer of flying buttresses has a different function than the bottom layer and should not just be seen as a reinforcement of the bottom layer. This would mean the second layer of flyers of the St John would be necessary, a statement that Glaudemans wholeheartedly agrees with. Glaudemans also believes in the expertise of the building masters, who new how much counterweight was necessary in the flying buttresses and does not think they would add such a specific element just for show. Smits does not agree the builders were that accurate, due to lack of precise calculation technology in those times.

To shed some light on the issue, a comparison is made with the Dom Church in Utrecht, a similar sized cathedral to the St John of Den Bosch. This comparison shows that, even with a greater ceiling height than the St John, one layer of flyers could suffice. However, each cathedral is different and might require different elements for different reasons. To be completely certain whether the secondary row of flyers is superfluous in the St John Cathedral is impossible, at least not without removing the flyers in question and waiting for the cathedral roof to collapse (which of course is not an option).

Perhaps the reason for the double layer of flyers lies in the building methods used in the late Middle Ages. In those days, construction methods and elements were applied based on example and practice. The use of two-tiered flying buttresses was effective in for example the cathedral of Amiens, which the St John may or may not have been based on, at least in floorplan. So whether or not the double row was completely necessary they might have been added because of successful application in the past; if it worked on those cathedrals, it was bound to work on the St John. The truth is that the St John is the one cathedral of the Netherlands that is closest to the original French cathedrals in structure. This could also explain the choice to copy the double flying buttresses, that are not found anywhere else in The Netherlands.

This is all disregarding the aesthetic and stylistic reasons they would have for adding the flying buttresses. In terms of aesthetics, the flyers place the cathedral in the Gothic style, fashionable in the time period when it was redesigned. During that period churches and cathedral also represented the connection with God and the divine. The flying buttresses could be seen as a heavenly arch, giving a light, ephemeral quality to the cathedral, while it was built with heavy materials like stone and brick.

The ornaments on the flyers also show the importance of pictures to the people of the late middle ages, who were often illiterate. The figurines most likely represented well-known stories, morals and sayings. They meant something to the general public that we can no longer fully comprehend, i.e. the popular culture of the Middle Ages. A particularly appealing theory by Smits is that all figures together represent humanity and the struggles and vices of their earthly life. Though it is not a proven theory and probably never will be, it would explain the variety of jobs, virtues and demons depicted.

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Last Name, First Name of author. Name of Collection. Name of Repository, Location of Repository.

Appendices

Appendix 1: Notes interview R. Glaudemans

Summary of interview with Dr Ronald Glaudemans, who has obtained a doctorate on the subject of the St John's Cathedral. The interview was conducted in Dutch, the notes from the interview that appear below have been translated to English.

Q1: Are there any authentic archival pieces and texts about the building and design process of the St John that have been preserved?

- Very little texts have been recovered from the time that the cathedral was built, they were lost in time or not kept at all by the architects/building masters. Some receipts were kept in the cathedrals administration of building materials, but no drawings. In the Middle Ages not many people could read or write, so there probably was not much written about the process. There are other cathedrals like Leuven (??) that were more fortunate.
- Most of the information about the building process and techniques has been deduced from archaeological discoveries during the restauration from 1999-2010 [Glaudemans was present on the site during the process to assess and document findings].
- After the research [Glaudemans] reconstructed the cathedral in its entirety in a 3D model, but special was that he built the 3D model in the same order as the actual cathedral was expected to have been built. This eventually showed some errors in those assumptions as certain steps were not possible in the experiment as previously assumed.
- Parts of the cathedral where wood was used, mainly the roof construction, could be dated accurately by wood dating by the year rings. Very accurate for time and location of origin of the wood.
- There were also some markings found on stone parts, made by the builders/architects which could indicate a certain origin period based on knowledge of the building masters of that time.

Q2: Are the flying buttresses structurally necessary for the St. John Cathedral?

- Yes! The cathedral has a stone vault for the ceiling construction, which is very heavy and produces a lot of outward thrust that needs to be compensated. That requires a lot of mass to counteract these forces. The notion that the flying buttresses could have been smaller or some could have been omitted is false. Without the flying buttresses the roof and loadbearing parts holding it up would have begun to shift.
- It is important to add flying buttresses as soon as possible during the construction phase of the roof, otherwise it could collapse, which was the case with the Dom Cathedral in Utrecht. There the nave came tumbling down because they left the construction of the flying buttresses for too long.
- Usually to prevent this a temporary bracing is added in the places where flying buttresses will be added later on, just to make sure the roof does not cave in. In the case of the St. John Cathedral the builders added a temporary steel bracing at the sides of the transept. In the dissertation I elaborate on it further.
- It was possible with this cathedral to add the heavy, stone roof and complementary flying buttresses because of the ground, which as mostly sand here in the south of The Netherlands. Sand is supportive enough for these kinds of heavy constructions. Up north, near Amsterdam for example, this would not be possible because the ground is softer there. There it is necessary to use lighter, wooden constructions for the roof, otherwise the

cathedral will sink and the shifting will damage the roofing system. Wood is more pliable as well, while stone construction could crack in these conditions.
Flying buttresses are not useful in these conditions, because they would also get damaged.

Q3: What was the thought behind the ornaments on top of the flying buttresses?

- This is a unique feature of this cathedral, not often seen anywhere else on churches or cathedrals. This is the earliest discovery of these kind of decorations on flying buttresses, but evidence of earlier occasions could have been lost, so this conclusion is not conclusive. There is a later cathedral that had similar figurines as ornamentation on the flying buttresses, somewhere in France, but that is it.
- The Dom does have crockets (a leaflike Gothic ornament) on its flying buttresses, but no figurines.
- The St John Cathedral also has statues placed on the top of the buttresses supporting the flying buttresses. These seem to only fulfil an ornamental role, but their weight does in fact contribute to the counteracting of the outward forces coming from the roof vault. This is also the case for the little figurines on top of the flyers. While building the cathedral the weight of these ornaments was taken into account when determining how much mass was necessary to counteract the outward roof forces. Heavier ornamentation meant the flyers could be smaller, more delicate.
- The ornamentation is often forgotten in the evaluation of the construction of cathedrals. It is seen as decoration and nothing more, but it does have a function. This is the problem of the research being done into these cathedrals. It is usually left to historians, who treat the ornaments like art that is separate from the building they are mounted onto. Their analysis has no connection to the building construction. No architects or constructors are consulted during these research projects, they do not work together in any way. This is something I am trying to improve in the field of architectural history, by combining both aspects and synthesising them. That is why my book title refers to ‘building sculptures’, not just ‘sculptures’, they are an integral part of the construction as much as the walls or roof.
  They are added during construction, not after. This is visible in the way that these sculptures have no connection seams where the are connected to the stone elements, they are the elements themselves.

Q4: What material was used for the flying buttresses and what can you tell me about its properties?

- The side-aisles, the nave and its flying buttresses are made from sandstone, while the choir and its flying buttresses are made of tuff. This difference is the result of changing trade habits. Tuff was a lighter and cheaper type of stone to use in constructions and was therefore more widely used that sandstone in the time that the choir was built. However, at some point the Rhine offered a cheaper way of importing sandstone from Germany, and they changed from tuff to sandstone.
- Tuff is a volcanic rock, which makes it lighter and more porous. Its lower weight does make it better for roof construction because it provides less outward forces on the construction, but it is also more prone to weathering. The flying buttresses made from Tuff were in a worse shape than the ones from sandstone.
- There is one receipt for stone intended for the flying buttresses that has been preserved from around 1500.

Q5: What happened to the flying buttresses during the restauration in the 19th century?

- In 1855 the St John was one of the first restauration projects done in the Netherlands and surrounding areas. They knew nothing about it, how it should be done. They looked to the building process of the cathedral of Keulen for inspiration, but of course this was not a restoration but still the initial construction that was being finished. This meant that the restaurateurs assumed the only way to restore the cathedral was to rebuild parts entirely with new material. Some of the flying buttresses and the figurines on top were completely replaced during this process. It was only later that they learned how to restore buildings while keeping the original construction and materials intact.
- A lot of the figurines on top of the flyers were in bad shape, some unrecognisable, so many were replaced and the missing figurines were redesigned, adding the building masters of the cathedral to them, while the original figurines were usually depictions of mythical creatures or biblical figures.

Q6: What can you tell me about the meaning of the figurines on top of the flying buttresses?

- During the middle ages not a lot of people could read or write so messages were conveyed among the general public by way of images. These figurines probably depict specific messages that were relevant to society in those days, like sayings or superstitions. Unfortunately the lack of scriptures – again due to illiteracy – means these specific meanings have also been lost. Some figurines have been interpreted but many remain a mystery.

Q7: Going back to the flying buttress as a structural element, is what is their origin?

- Though the origin of flying buttress is usually attributed to the Notre Dame in Paris, there are some predecessors that have been found in Italy and Jugoslavia that are dated earlier than the Notre Dame. These usually resemble buttresses, but they have holes in them, like arches or windowlike holes. Unfortunately there hasn't been a lot of research done on this subject, because for some reason it is not considered structurally relevant for modern day architecture. It is seen as somewhat primitive, also because they originate from a time when there were no texts written about the construction yet. Pre 20th century architecture is also not usually taught at universities because of its lacking relevance to modern architecture. The chances of more research done on this subjects therefore remain slim, which is a shame.
- Construction, especially of cathedrals was a highly valued job during the middle ages and building masters travelled across countries to apply their expertise. It was a competitive business, with building owners trying to hijack the best builders from their other clients to work on their projects. The building masters were experts in their field, they new how structural forces and building techniques worked from experience, without the advanced technology to calculate them like we have nowadays.
- Because they travelled so much, they brought the different building styles with them, like the Gothic style was brought from Paris to Brabant in the Netherlands.

Appendix 2: Photographs site visit to the St John Cathedral

- Visit conducted by the author on 15 february 2024

Northside of the Nave with the flying buttresses and flyer chairs.

Northside of the Nave with the flying buttresses and flyer chairs and part of the north transept.

The flying buttresses on the west side of the south transept.

The top flying buttress on the west side of the south transept, crockets visible.

The flying buttresses on the east side of the south transept, with figurines.

Pier buttresses of the choir.

First flyer of the southside of the nave, figurines visible.

Flyers on the southside of the nave.

Flyers of the south transept

From buttress to flying buttress, southside nave.

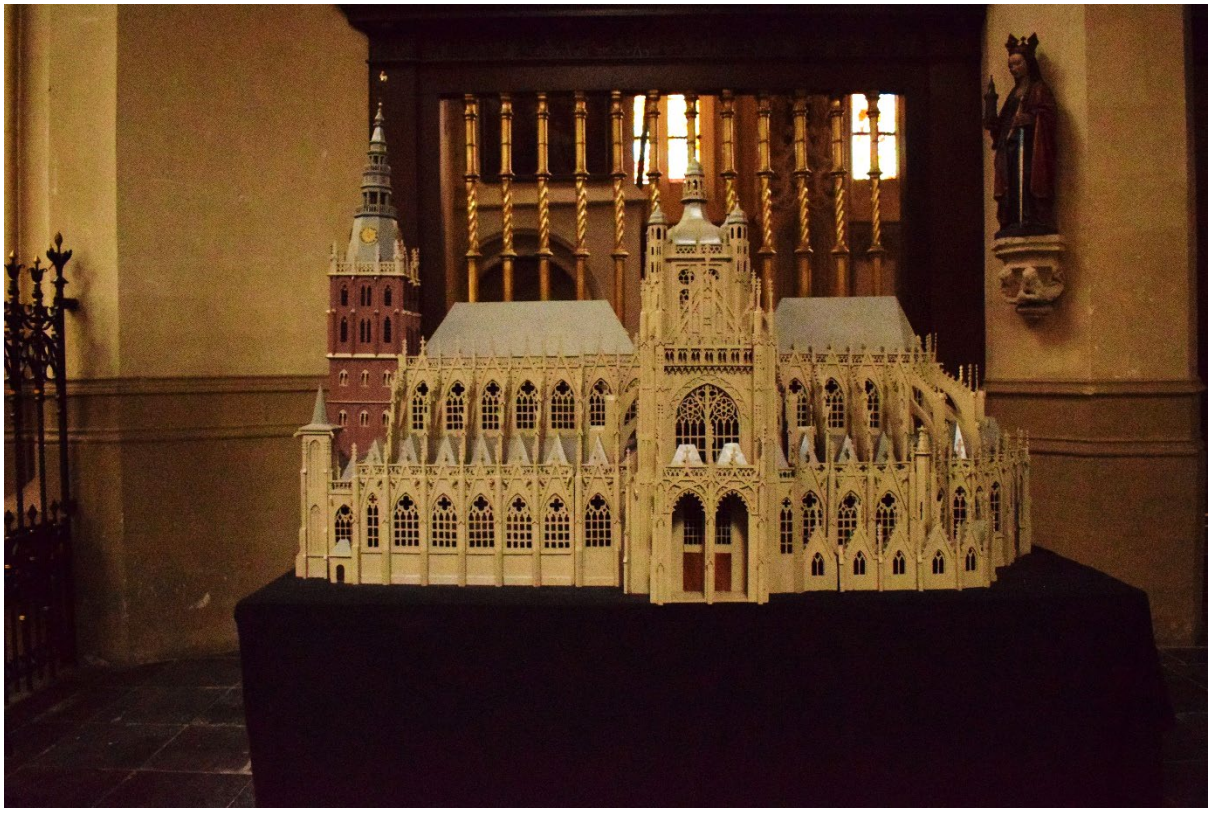
Flyers southside of the nave

Flyer of the choir, southside.

Flyers southside of the choir

First flyer of the southside of the nave.

Large windows and vault of the ambulatory.



Scale model of the cathedral