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THE ACOUSTIC DESIGN OF THE CONCERTGEBOUW, AMSTERDAM, AND RESOLUTION OF THE HALL'S EARLY ACOUSTICAL DIFFICULTIES

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1 INTRODUCTION

The Concertgebouw opened on 11 April 1888 to tremendous excitement and anticipation in the musical and cultural community of Amsterdam. The building had been conceived as a musical centre that would be the impetus for bringing Amsterdam's musical life to international stature. Great efforts had been made to design the hall for fine acoustics, with much public discussion of which forms and models would ensure acoustic success. Great was the disappointment, therefore, when the hall opened to mixed opinions of its acoustics. The chief complaints were that the room was excessively resonant, and that balance between the brass and strings was poor. Performances over the ensuing months put the room's acoustical character to the test of public and musical taste, and after the newly formed Concertgebouw Orchestra gave its first concert on 3 November 1888, it was clear that there was "something lacking" in the hall's acoustics.[1]

The Grote Zaal at the Concertgebouw these days is regarded as a pinnacle of acoustic excellence, and its famed reverberation time of 2.0 seconds (occupied) at mid frequencies is frequently cited as a basic parameter for concert hall design. It is hard, therefore, to conceive of the hall's being considered acoustically deficient when it opened. Yet these acoustic detriments were considered so severe that they contributed to poor attendance in the early years, which in turn contributed to such financial difficulties that the institution nearly did not survive.

Fig. 1 The Concertgebouw between 1891 and 1899.

This paper discusses the process of designing the Concertgebouw for acoustical excellence, and gradual resolution of the hall's acoustical deficiencies between 1888 and 1899. The research also reveals the origins of the room's distinctive characteristics that set it apart from other halls of international standing – its unusually great stage height and room width. Sources for this research include published accounts of the work of the Concertgebouw architect, A.L. van Gendt, detailed histories of the early years of the Concertgebouw, which include newspaper reports, programming and management records, and annotated scores of the conductor Willem Mengelberg.[2]

2 DESIGN FOR FINE ACOUSTICS

2.1 Context

On 26 June 1881 an article appeared in the weekly, *De Amsterdammer,* calling for a new concert hall to be built in Amsterdam. The author, G.W.W.C Hayward, proposed that the enterprise should be a private initiative, and that the hall, though it did not need to be luxurious, should be worthy of the city and prove that beside its material interests Amsterdam also aspired to a higher good.[3] Amsterdam at that time was a prosperous and rapidly growing mercantile city. Around 1880 a general revival of Dutch cultural life began, and the building of the Concertgebouw was part of this "awakened public spirit".[4]

There had been talk of building a fine concert hall for Amsterdam before this time, but the immediate impetus for Hayward's letter was the announcement that the Parkzaal, Amsterdam's largest concert building, was to be demolished. The Parkzaal was famous for summer matinee concerts, as a place to listen to music, drink coffee and alcohol, and chat. Its kitchen and convivial atmosphere were famous; its acoustics reputedly were terrible.[5]

Fig. 2. The Parkzaal. Note the orchestra in relation to the balcony

There were several other halls for music performances in Amsterdam at the time, including small chamber music rooms at the Odéon and the Felix Meritis Society, and a larger hall at the Paleis voor Volksvlijt. Of these, only the room at the Felix Meritis Society was considered to be excellent acoustically. Thus the acoustics of the Felix Meritis Society were the yardstick by which Amsterdammers up to this time had experienced and judged acoustical excellence.

As in other parts of northern Europe, in the Netherlands there was a strong choral movement, with performances involving huge choirs and orchestras assembled for festival performances. Both the Paleis and the Parkzaal had small orchestras, but in 1881 Amsterdam had no permanent professional symphony orchestra. Brahms had commented in 1879 on the low level of musical performance in Amsterdam.[6] Hayward's letter therefore was a clarion call to Amsterdam to bring its musical life to the level of other major European cities of the time.

Fig. 3. The chamber music room at the Felix Meritis Society

.2.2 Early generative ideas

Soon after Hayward's letter was published, a committee of eminent citizens of Amsterdam was formed to organize the effort to build a new concert facility and establish a dedicated orchestra to be based there. The committee sought input from Amsterdam's musical societies, particularly the Maatschappij tot Bevordering der Toonkunst (Society for the Advancement of Music), and from P.J.H. Cuypers, who was architect of the Central Railway Station and the Rijksmuseum. By March 1882 the committee was ready to present detailed proposals to a public meeting of Amsterdam citizens. This meeting resolved that the project should go ahead.[7]

In his letter, Hayward had proposed the Tonhalle in Düsseldorf (which had opened in 1865) as a model for the new concert hall, because he considered it an "ideal concert hall" in its simplicity and functionality.[8] With approximately 2000 seats it was also similar in size to the old Parkzaal.

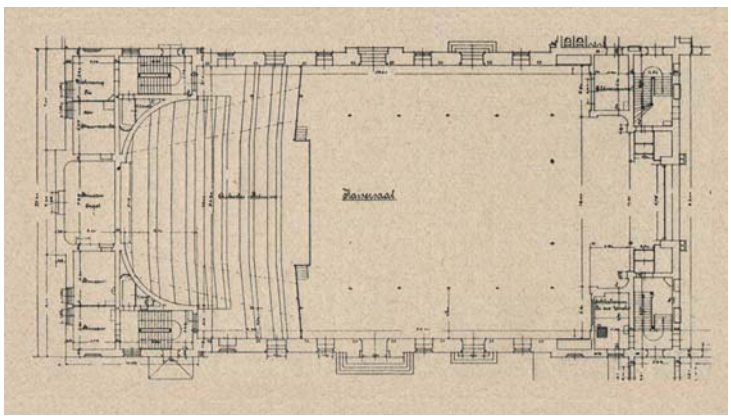


Fig. 4. The Kaisersaal at the Tonhalle, Düsseldorf - plan.

The proposal put forward by the committee in March 1882 was for a large hall to seat 2000+ people, with a stage to accommodate an orchestra of 120 and chorus of 500. The model for the new hall was to be the Düsseldorf Tonhalle. There was also to be a garden for summer concerts, which were expected to be an important source of income, and a small hall for chamber music. A design competition would be held, with five invited Dutch architects. The proposed site was on the outskirts of Amsterdam at the border of the municipality of Niewer Amstel, near the Rijksmuseum.[9]

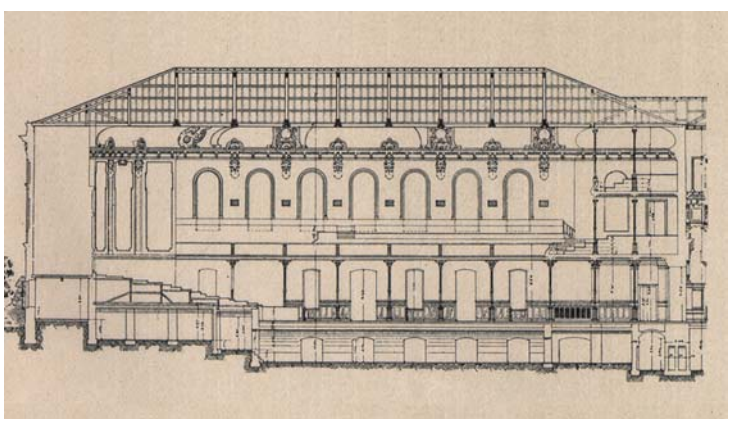


Fig. 5. The Kaisersaal at the Tonhalle, Düsseldorf. Long section.

Following this public meeting there was public discussion on the suitability of the Düsseldorf model. W.F. Thooft, a well-known musician from Rotterdam who had lived in Düsseldorf, wrote in the A*lgemeed Handelsblad* (21 March 1882) that the sound in the Düsseldorf Tonhalle was poor, the strings especially sounded wooden and colourless and the wind instruments were variously affected by "bad resonance". Thooft considered these problems to be the result of adding balconies in a

rectangular hall. He argued that since a hall for 2000+ people would be too long if there were no balconies, because the sound would become weak if it traveled too far, it was necessary to find a shape that would accommodate balconies with no acoustic detriment. “Acoustics is still far too uncertain a science to give all the exact reasons for a bad sound,” he wrote, speculating that in a square hall corners and holes would appear opposite the orchestra in which the sound would get stuck. The ideal form for avoiding this, he argued, was the oval or round; the best solution for the Concertgebouw therefore was to take the model of the oval Felix Meritis hall and enlarge it. Thooft also wrote that it was desirable for acoustic quality to have spaces around the full perimeter of the concert room so that the walls were not in immediate contact with the open air. He was expressing a widely-held view at the time that attributed the exceptional acoustical quality of the Felix Meritis hall and the Altes Gewandhaus in Leipzig to this arrangement. He argued that “even the application of a hollow space behind the orchestra” would give good acoustic results.[10]

2.3 The design competition

It appears that the committee was only partly swayed by this late discussion on acoustic form. The design competition was announced on 9 June 1882, and although there was subsequently some amendment of the terms, the parameters were close to the proposals outlined publicly in March. The Tonhalle in Düsseldorf was not the official model for the large hall, but the Düsseldorf plans were circulated and much discussed among the competitors and jury, and ultimately all the submitted designs showed the influence of the Düsseldorf hall. The Felix Meritis hall was the model for the small chamber music hall.[11]

Under the initial terms of the competition, the large hall could be rectangular, round or oval, approx. 40m wide and long enough to accommodate an audience of 2000. A balcony was permitted. The stage was to accommodate 500 singers and an orchestra of 120, and was to be built in the form of an amphitheater. Subsequent committee discussions included whether the floor should be sloped (for sightlines and acoustics). Ultimately the shape and size of the room was left to the architects, the stage was to slant upward, 35m^2 was to be provided for a concert organ, and each seat space was to be allocated 0.55m x 0.75m @ 0.8m row space. Submissions were due on October 1, 1882.

Figures 6 and 7 show the competition drawings of A.L. van Gendt, who ultimately became the architect for the project. The audience area was 35m wide x 44 m long, with one balcony. The stage was narrower than the seating area, and was steeply sloped to the level of the balcony, with a central flat area for the orchestra and choral seating on either side. The ceiling was kept low to reduce cost.

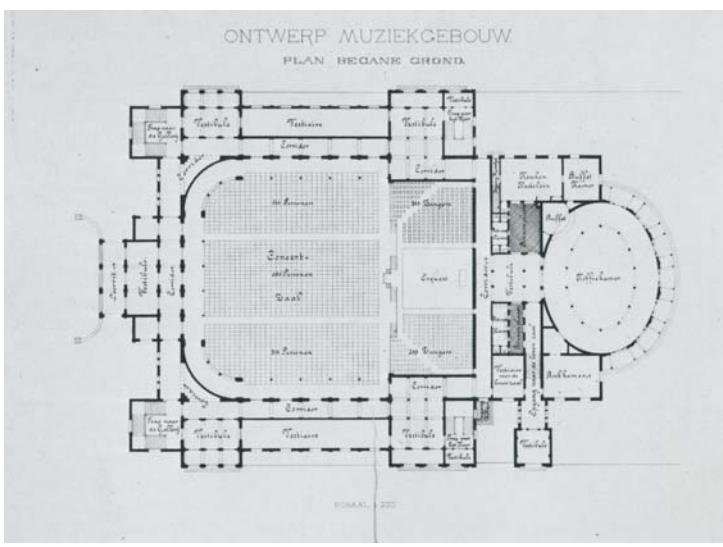


Fig. 6. van Gendt’s competition design – plan.

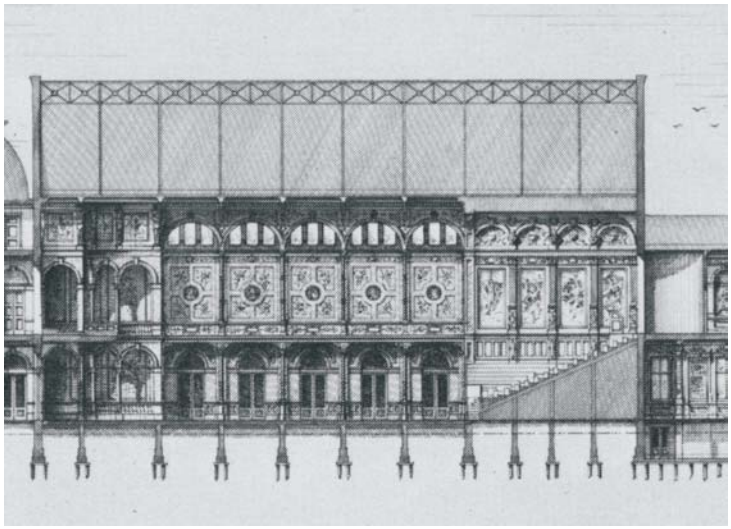


Fig. 7. van Gendt's competition design – section.

There was no winner for the first round of the competition, however. Van Gendt's room was considered too wide in relation to its length. Other submissions were criticized for being too wide, too square, having too deep a balcony (at 11m deep), a glass ceiling, a plain flat ceiling, heavy ceiling framing, ceiling beams parallel to the stage, deep corners (where sound could be lost) – all these were considered detrimental for acoustics.[12]

Two architects were invited to modify their designs and resubmit drawings for a rectangular room with rounded corners – the first clear indication that the influence of the Gewandhaus was beginning to be felt in the design process. Van Gendt was asked to make his room narrower and to raise the ceiling. Both redesigns were rejected, but after some negotiation van Gendt was selected as architect, on the proviso that he refine his drawings further to meet the committee's requirements.[13]

Figure 8 shows van Gendt's revised competition design. The room is now narrower, 29.8m wide x 44 long, and the platform and the audience chamber are the same width. The side balconies stop short of the stage, probably as a development out of the original design. The stage still rises steeply to balcony level. The central orchestra area flanked on both sides with choral seating now incorporates risers, curved in "amphitheater" style.

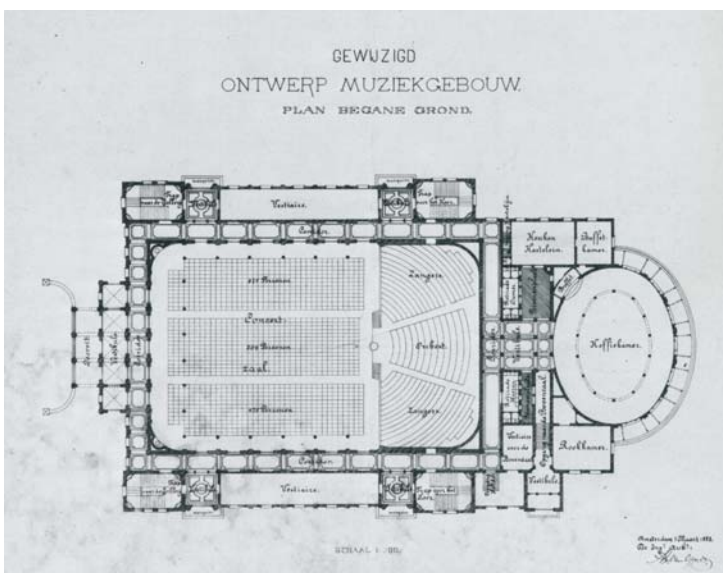


Fig.8. van Gendt's revised competition design, March 1883 – plan.

2.4 Evolution of the Design

Van Gendt became architect for the Concertgebouw on 6 April 1883. Figure 9 shows a revised section he prepared almost immediately at the request of some members of the committee, with a vestibule underneath the hall (to save space on a small site), and perimeter spaces surrounding the hall at all levels, similar to the plans for the Neues Gewandhaus in Leipzig.[14] The ground floor vestibule was ultimately not built because of cost, but from this time on the influence of the Gewandhaus became increasingly apparent in the design of the Concertgebouw.

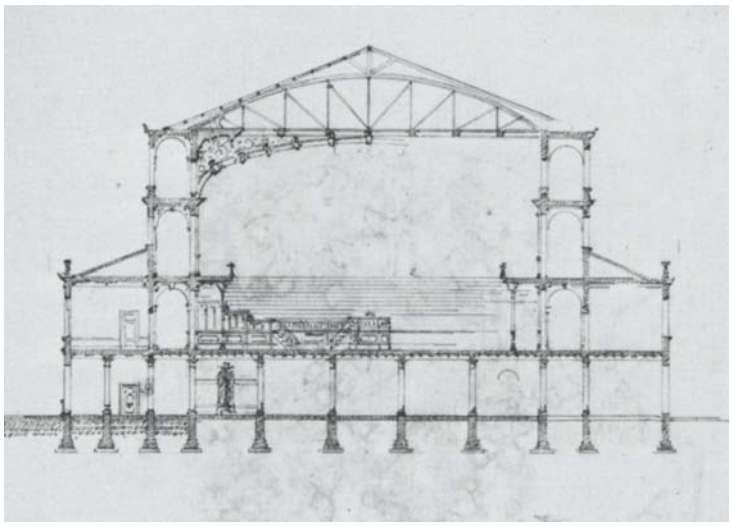


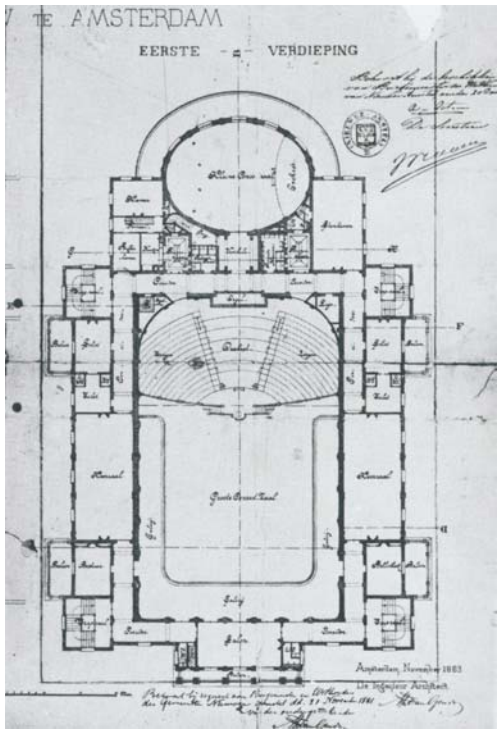
Fig. 9. Revised section, April 1883.

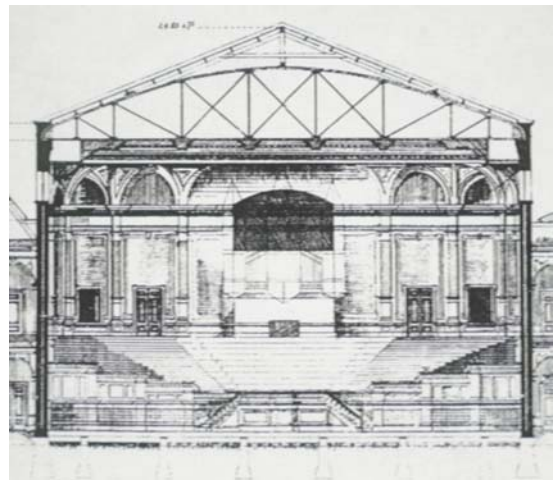
It is perhaps not surprising that the influence of the Gewandhaus came late in the design process. The Neues Gewandhaus was still under construction (it opened in 1884), and the existing (Altes) Gewandhaus, notwithstanding its acoustic reputation, was a very small room built originally for 460 people, and subsequently modified to hold around 1000 in very cramped conditions. Principles from the old Gewandhaus were being applied to the design of the new hall – including the rectangular form with rounded corners, and the spaces all around – but the outcome was not yet known.

Soon after van Gendt was selected as architect, members of the Concertgebouw committee (which was now an incorporated company) and Van Gendt or a representative of his firm visited Leipzig. The goal of the visit was to study aspects of the design for the new Gewandhaus – the seats, ventilation and heating system, and the organ.

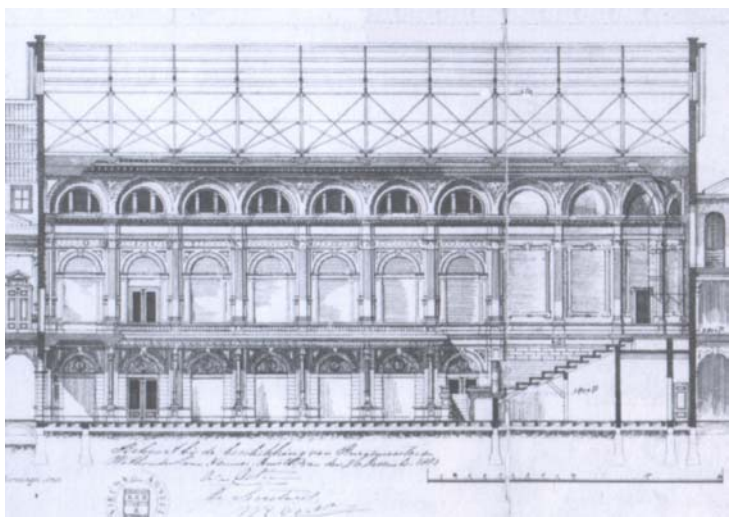
Fig. 10. The Neues Gewandhaus, Leipzig.

There was much pressure in Amsterdam to begin work on the new hall, so the foundations were begun early, and were in fact completed a few days before van Gendt's definitive plans for the building were approved by the committee (on 22 November 1883). Figures 11-13 show these drawings. The room was now 27.8m wide x 44m long, and 17.5m high. The orchestra platform still extends steeply to the balcony level, and it had been enlarged and reconfigured somewhat.





Above left:
Fig. 11. van Gendt's definitive design, November 1883 – plan.
Above:
Fig. 12. van Gendt's definitive design, November 1883 – cross-section.
Below:
Fig. 13. van Gendt's definitive design, November 1883 – long section.



By May 1884 work on the Concertgebouw was suspended because of a general financial downturn and because not enough funds had been raised. By the time work resumed in February 1885, the Neues Gewandhaus had opened and was known to be an acoustic masterpiece. There were now more changes to the Concertgebouw design after the work resumed, most notably to the

construction of the interior walls of the large concert hall, which were made thicker, with an air space, along the lines of the Gewandhaus construction. This heavier construction, which had not been provided for in the original foundation design, appears to have been responsible for the cracking of walls and sinking of the building which became apparent not long after opening and which ultimately led to a major renovation of the building in 1983. Towards the end of 1885 the stage was also enlarged by some committee members who had concluded that it would be too small for major choral works; their change was made "with the Gewandhaus in mind". The ultimate design of the Concertgebouw's heating and ventilation systems, and its organ, were strongly influenced by the Neues Gewandhaus. The deep ceiling coves are also reminiscent of the Neues Gewandhaus.

The building was completed in March 1887, but the opening was delayed for over a year because of the need to secure a mortgage as well as municipal wrangling between Amsterdam and Niewer Amstel over the provision of access roads, drainage and gas supply.

2.5 Precedent and Acoustic Design

From the above discussion it is clear that early parameters set by the committee had a defining influence on the design, and that the primary models for the hall were the Tonhalle in Düsseldorf and the Neues Gewandhaus in Leipzig.

The origin of the design of the orchestra platform is more of a puzzle. From the first of van Gendt's drawings the stage was high and steep, and extended to meet the (very high) sidewall balconies. References were made to the influence of the stage at the Gewandhaus, but the Gewandhaus stage was low, flanked by balconies, and had low, straight risers. There is an extension for the conductor's stand, and this may have influenced the configuration of the front of the Concertgebouw platform. The Düsseldorf platform may have suggested the overall proportion of stage to room, and partly have suggested the stage to balcony relationship, but like the Gewandhaus it was not steep and its risers were not curved. Where, then, did the request for an "amphitheater" stage come from? The answer may lie in Dutch choral tradition. At the Parkzaal the orchestra was situated in a semi-circular niche, on a platform that placed the musicians high in the room and extended up to the balcony level. An illustration of the Feestgebouw in Rotterdam (1854) – one of those wonderful, temporary choral festival buildings – also shows the chorus and orchestra high in the room. Certainly the platform size, which was to prove so problematic in the early days, was set by the requirement that it accommodate chorus and orchestra large enough for choral performances with very large forces.

3. FROM ACOUSTIC FAILURE TO SUCCESS

3.1 Opening

The Concertgebouw opened on 11 April 1888 to a packed house and stage filled to capacity. Henri Viotta conducted an orchestra of 120 players assembled for the occasion and a chorus of 500 drawn from several of Amsterdam's choral societies. The program included Beethoven's 9th Symphony and works by Wagner, Handel, Bach and Haydn.[15]

Most of the audience went home exhilarated, although after the concert the excitement was dampened somewhat by the congestion and delays when all the carriages attempted to leave simultaneously via the one open access road.[16]

Reports on the acoustics soon appeared in the press. The *Algemeen Handelsblad* (24 April 1888) reported that people in different parts of the hall had praised the acoustics, but also that resonance in some locations was strong. The magazine *Caecilia* also praised the acoustics.[17] Others had reservations. *Niews van den Dag* (13 April 1888) reported divided opinions on the acoustics depending upon where one was sitting, but nowhere was "without resonance". That article also

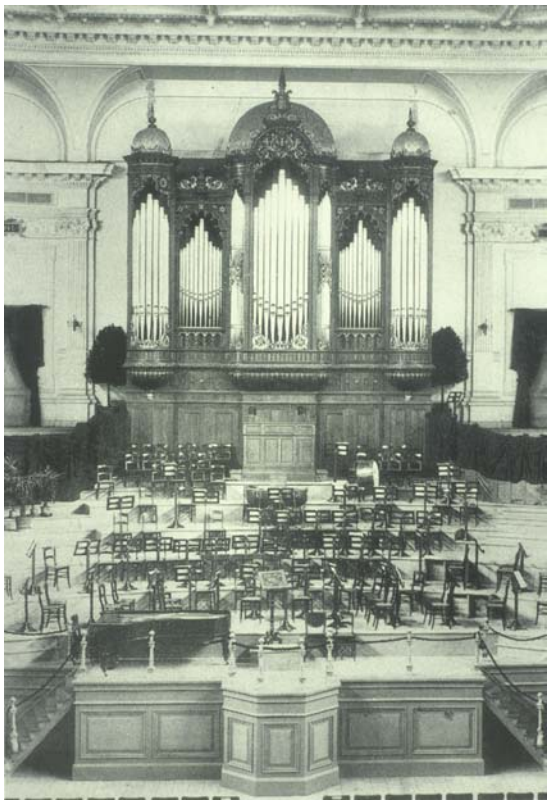
commented on the way the hall's acoustics brought out the fine nuances in vocal and violin solos, suggesting that the hall was perfect for solo performances.[18]

The Toonkunst Society's concert shortly thereafter was also filled to capacity, but this time the orchestra and chorus was smaller, and the space between the performers and the wall behind the platform was considered "a negative vacuum in relation to the acoustics." [19] The sound was weaker than at the opening concert.[20]

The first concert of the newly formed Concertgebouw Orchestra, with Willem Kes as its conductor, was held on 3 November 1888.There were only a few hundred people in the audience, and the orchestra of 66 musicians was only of moderate size. This was the first acoustic test of the room for symphony performances, and it confirmed that the hall "resonated" too strongly and that the brass overpowered the strings. The high hopes in musical circles for the "supremacy" of the new hall were turning to misgivings and fear that "this institute of art had major [acoustical] problems".[21] No doubt the nearly empty hall and the inexperienced orchestra exacerbated the situation.

3.2 Early Remedies

It was not immediately clear what was causing the acoustical problems. Some felt that the missing organ was the problem – the space for the future organ was covered by a heavy curtain. But when the organ was installed in 1891 the acoustic problems were not resolved, and some considered the sound to have become harsh and the balance problems even worse.



Other early remedies included adding drapes at the entrance doors, building a low screen at the back of the orchestra and covering this screen with thick drapes, and filling empty areas of the stage with potted plants, which it was hoped would "soak up the sound". Carpet was placed under the brass and percussion instruments, and would have been added in the aisles but for insufficient funds.

Inadequate access roads continued to plague the Concertgebouw, despite the efforts of the building management to persuade the city of Amsterdam and the municipality of Niewer Amstel to coordinate their urban development efforts. Concert attendance continued to be poor, except for occasional special performances such as the Christmas concert and other Toonkunst Society events, and occasional performances by stars such as Eugene d'Albert. The orchestra continued to be isolated in the centre of a largely empty stage. It was not until the very end of the century that audiences were regularly seated in the choral terraces at either side of the orchestra. Financial difficulties were so severe at this time that the institution and orchestra barely survived, and indeed in 1891 the orchestra's contract was for a time dissolved.

Fig. 14. The Concertgebouw after 1891, with screens, drapes and plants to help control the acoustics.

3.3 Solutions – Musical

The turning point for acoustical success came in 1895 with the appointment of Willem Mengelberg as conductor of the Concertgebouw Orchestra, and in the first concert of the 1896 season with the performance of Tchaikovsky's 6th Symphony, the Pathétique.

Mengelberg was only 24 when he took the post at the Concertgebouw. His first season in 1885-86 seems to have been relatively undistinguished, and some in the music community were doubting his suitability for the position. But Mengelberg opened the second season on 17 September 1896 with Tchaikovsky's 6th Symphony, and suddenly all changed – musically and acoustically.[23] The performance was described in the *Algemeen Handelsblad* (30 October 1896) as truly inspirational, a "wonder" of the concert room, an amazing psychological phenomenon. It was felt that Mengelberg and the Pathétique had established the orchestra's greatness, demonstrating that the orchestra could meet the demands of modern composition. Mengelberg was described as a conductor "in the grace of God". Most of all (from the point of view of acoustics) the brass did not overpower the strings, which suggested that the balance problems had been solved. At subsequent concerts over the next year the Pathétique was repeated thirteen times, drawing tremendous crowds.

The phenomenon is more striking when one realizes that Tchaikovsky's 4th Symphony had been performed by the Concertgebouw Orchestra two years earlier and had been received with indifference, and that the Pathétique had been performed eight months earlier at the Paleis in Amsterdam under the baton of Russian conductor Saronoff, a friend of Tchaikovsky, where it was received with interest but nothing approaching the enthusiasm that greeted the Mengelberg performances. What was at work here?

Mengelberg was a very different conductor from his predecessor Willem Kes. Kes was a conductor more in the classic style, maintaining steady tempos and leading the music in a straightforward, non-interpretational way. Mengelberg, on the other hand, became one of the great international star conductors of the late Romantic/early twentieth century era. His approach to conducting was strongly personal and interpretational but always, he maintained, in order to realize the true intention of the composer.[24] His conducting was precise, with wider gestures than his predecessor. His focus was on unity and precision in the orchestra, and through these on expression of the phrasing, on the broad sweep of beautiful melodies and the emotional effect of the music. His interpretations were known for wide fluctuations in tempo, grand dynamic range and sweep, a "lavish" gliding from one tone to the next in the strings (portamento), and an emphasis on instrumental timbre and color, He made widespread changes to composers' scores in order to achieve these effects. Whether Mengelberg was a conductor in this style in his first season is not known, but it seems clear that by the first concert of the second season he was.

Mengelberg's annotated score of Tchaikovsky's 6th Symphony is now held in the Haags Gemeentmuseum.[25] It is a remarkable document, full of a vast number of annotations made by Mengelberg over the years, including significant modifications to tempo and dynamics, and to orchestration, to bring out melodic lines and particular effects. These changes to the score show Mengelberg's process of shaping a performance for effect, revealing a response not only to the score and to Mengelberg's idea of the composer's intentions, but also to the musicianship of the players in the orchestra - and to the acoustics of the room.

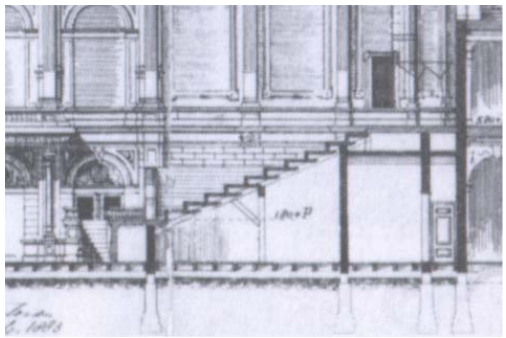
Tchaikovsky's Pathétique is an intensely emotional symphony, with broad lyrical melodies, rhythmic and chromatic intensity, and remarkable writing for "choirs" of instruments that combines timbres of instruments in different sections of the orchestra to achieve specifically nuanced sound colors. This homophonic writing combines unusual groups of instruments – a clarinet solo against sustained notes in the woodwinds, trombones and tuba, for example, or horn combined with viola, or horns, trumpets and trombones with first violins and violas. These qualities in Tchaikovsky's writing meshed with Mengelberg's conducting style to produce a passionate intensity that was enhanced in the reverberant Concertgebouw. Moreover, the blended sound across groups of brass, woodwind or string instruments would have given the impression that the balance problem had been solved.

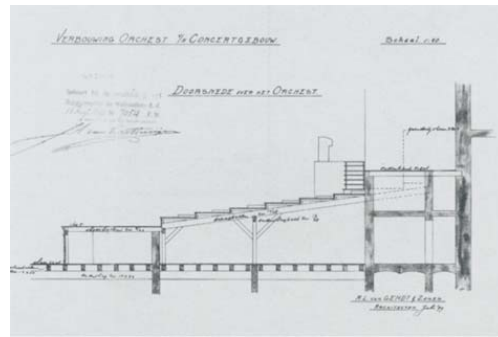
The orchestra by this time was also much improved. Kes's focus had been on a steady improvement in the orchestra's standards and educating the listening habits of the audience. Under Mengelberg's direction the orchestra soon grew to international recognition. The orchestra expanded from 66 permanent members in 1885 to 86 in 1907; though small by international standards at that time, it was augmented to 100 or more for particular performances. New modern instruments were acquired, professional conditions improved. And, of course, more highly skilled musicians are much more able to shape their sound to the requirements of score and acoustics.

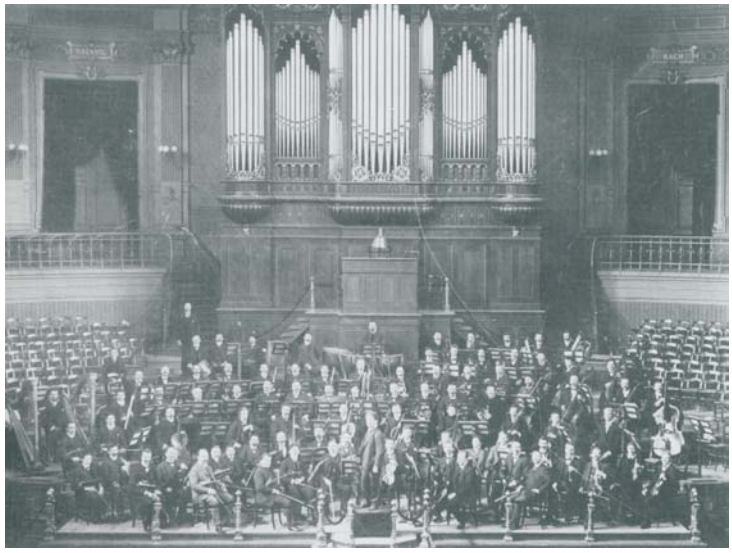
One final factor in this "turnaround" is non-musical. In 1893 the horse tram was extended closer to the Concertgebouw, and in 1895 the municipal boundaries were changed.[25] Roads began to be built, neighbourhoods rapidly grew up adjacent to the Concertgebouw, and the "Concertgebouw was released from its isolation".[26] At last it was becoming easy for audiences to attend Concertgebouw concerts, and after Mengelberg and Tchaikovsky's 6th in 1896 the audience came in droves.

3.4 Solutions – Architectural

It was soon discovered that Mengelberg and the Pathétique had not solved the hall's balance problems. Finally, in 1899 the plan that had been thought about – and debated – for years came to fruition. The very steep stage was rebuilt and reduced in height 20 cm at the front, 1.2 m at the sides, and 2.3 m at the rear.[27] This not only reduced the excessive vertical spacing between the orchestra sections, but also exposed a reflective surface at the rear of the orchestra beneath the organ. Sightlines for the conductor were also improved.[28] When the hall reopened on 11 September 1899, the balance between the sections was vastly improved. It was declared in the *Niews van den Dag* (12 September 1899) that "all the necessities for world renown were now present".[29]







Above:
Figs 15 and 16. Sections through the orchestra podium before and after the renovation.

Left:
Fig. 17. The Concertgebouw Orchestra with conductor Willem Mengelberg at the Concertgebouw in 1907.

4. DISCUSSION

It is clear that the resolution of the Concertgebouw's early acoustical difficulties involved an interrelationship of musical, architectural, and social factors; different combinations of these factors came together to solve the problems of orchestral balance and excessive "resonance".

The problem of orchestral balance was finally solved by the rebuilding of the stage end of the room to provide much less vertical spacing through the orchestra and a central rear wall behind the musicians. The evidence suggests also that improvement in the orchestra's standards and changes in performance practice helped to address the problem, but that the musical changes alone were not sufficient.

Resolution of the "resonance" problem was more oblique. The Concertgebouw is a reverberant room (see Table 1), and there is no doubt that the ears of musicians and audience accustomed to the excellent small chamber music room at the Felix Meritis Society would have found the enormously longer reverberation time strange – at least at first. Poor attendance in the early days, and a relatively small and inexperienced orchestra on a very large orchestra platform, only made the situation even worse.

Table 1. Concertgebouw – Some Acoustic Data[30]

Room dimensions	27.8m W x 44 m L x 17.5 H	91' W x 144' L x 57' H
Volume	19,500 m3	690,000 ft 3
Audience	2037	
Orchestra	120 (orchestra size the stage was designed for)	
Chorus	506 (present maximum capacity)	
Volume per person (audience only)	9.6 m3	339 ft3
Volume per person (incl. musicians)	7.3 m3	260 ft3
RT occupied	2.0 sec av. at mid frequencies	
RT unoccupied	2.6 sec av. at mid frequencies	

Comments on the excessive resonance seem to have faded gradually. The reports on Mengelberg and the Pathétique in 1886 make no mention of it, and focus instead on the perceived resolution of balance between brass and strings. Mengelberg's conducting style and the writing of the Pathétique were ideally suited to the reverberant responsiveness of the Concertgebouw; the musicians were much better able to play responsively to the acoustics of the room; and the musical imagination of Amsterdam was captivated. It seems that a new phase in public musical taste was ushered in with the Mengelberg era, and it included a new appreciation of the Concertgebouw's reverberance.

It remains true that the reverberation time of the Concertgebouw can be problematic, particularly in rehearsal and for more classical works with small ensembles, especially when audiences are small. Mengelberg experimented with screens to help him hear the orchestra during rehearsal, and many conductors since have used curtains extending from ceiling to floor at the front of the audience area to help control excessive reverberation during rehearsals. Conductors and musicians in the Concertgebouw Orchestra today still consciously adapt their performance techniques to the room's reverberance.[31]

The orchestra platform has been rebuilt several times since 1899. Today the choral terraces again extend to the balcony level, while the orchestra remains in the centre on low risers with the wall at the base of the organ as a reflective surface behind them.

5. REFERENCES AND NOTES

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2. Major scholarly histories on the Concertgebouw, which were the sources for the core information in this paper, are S.A.M Bottenheim, *Geschiedenis Van Het Concertgebouw.* Vols. 1-2, Joost Van Den Vondel, Amsterdam (1948-49), and *Historie en Kroniek vanhet Concertgebouw en het Concertgebouworkest,* 2 Vols, Amsterdam, Concertgebouw.
3. Details of Hayward's letter are in Lydia Lansink, 'De akoestiek van het Concertgebouw historisch bezien,' *Preludium,* 36(8), 35-45 (April 1978). Also in *Historie en Kroniek*, Vol 1, 69.
4. Bottenheim, Vol. 1, 7. Also see Eduard Reeser, *Ein eeuw Nederlandse musiek, 1815-1915.* Amsterdam, Elsevier, 5. (1960).
5. *Preludium*, 35.
6. *Preludium*, 35.
7. Detailed accounts of the work of the committee are found in Bottenheim, Vol. 1, 11-24, and *Historie en Kroniek*, Vol. 1, 74-75.
8. *Historie en Kroniek*, Vol. 1, 69; *Preludium*, 36.
9. *Historie en Kroniek*, Vol. 1, 73.
10. Detailed account in Bottenheim, Vol. 1, 20-22.
11. Detailed discussion of the design competition appears in *Historie en Kroniek,* Vik 1m 74-76 and *Preludium,* 37-38.
12. *Historie en Kroniek*, Vol. 1, 78-79.
13. *Preludium*, 38.
14. Information here is drawn mainly from the detailed account of the design process is found in *Historie en Kroniek*, Vol. 1, 81-90, also in *Preludium.*
15. Bottenheim, Vol. 1, 56. There are reports of a chorus of 600, and 750 people on the stage, but it is not clear if these are exaggerations, or whether the chorus was on occasions very crowded.
16. *Preludium*, 34-35.
17. Bottenheim, Vol. 1, 56-57.
18. *Preludium*, 35.
19. Bottenheim, Vol. 1, 65.
20. *Historie en Kroniek*, Vol. 2, 73, citing *Algemeen Handelsblad,* 24 April 1888.
21. Berckenhoff, cited in *Historie en Kroniek*, Vol. 2, 73.
22. *Preludium*, 44.
23. The primary source for this account is Bottenheim, Vol. 2, 8, 13-16.
24. Clemens Romijn, 'The Performer must help the Creator', *Willem Mengelberg, Conductor,* Haags Gemeentemuseum, 212-235. (1995).
25. *Historie en Kroniek*, Vol. 1, 91.
26. Bottenheim, Vol. 2, 12.
27. *Historie en Kroniek*, Vol. 2, 90.
28. Bottenheim, Vol. 2, 59.
29. *Historie en Kroniek*, Vol. 2, 90.
30. Sources for the data in table 1: Dimensions from historical documents and drawings; audience and chorus numbers are the current capacity; reverberation times are averages of the data given in Leo Beranek, *Concert and opera halls: how they sound.* Acoustical Society of America, 613-14. (1996).
31. Truus de Leur, former musicologist for the Royal Concertgebouw Orchestra, pers. comm.. and from a biography of Eduard van Beinum (in preparation).

6. ACKNOWLEDGMENTS

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