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PAUL SCARBROUGH
RUSSELL TODD
CHRISTOPHER BLAIR
ANTHONY NITTOLI

93 North Main Street, South Norwalk, CT 06854 • TEL: 203-299-1904 • FAX:203-299-1905 • www.akustiks.net

Acoustical Survey Report for the

Watford Colosseum

Prepared for:
Classic Concerts Trust
Jonathan Brett, Artistic Director

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Executive Summary

The results of objective and subjective assessments confirm that the acoustics of the Watford Colosseum are exceptional. This acoustical survey, commissioned by the Classic Concerts Trust, revealed that the venue is easily the best concert hall of its size in greater London or its environs and among the top rank of halls in Europe. The Watford Colosseum possesses a lively acoustic that is well suited to the presentation of live classical music. Its acoustics are notable for the following attributes:

- pleasing reverberance
- good articulation and clarity
- an intimate sound quality
- a reasonable sense of being enveloped by or immersed in the music
- strong sense of impact
- rich and warm quality to bass sound
- good balance between sections of the orchestra

To gain a better understanding of the acoustical qualities of the Colosseum, we made a physical inspection of the auditorium, conducted a series of acoustic measurements in the space and completed a study of basic plans for the building. These studies revealed that the acoustics of the Colosseum compare favorably with some of the better-known concert halls in the world such as Symphony Hall in Boston and the Musikvereinssaal in Vienna. On the basis of these investigations it is quite reasonable to claim that the Colosseum ranks among the best medium-scale concert spaces in Europe.

Our studies indicate that the acoustical quality of the Colosseum is largely dependant upon the following physical features:

- the rectangular geometry of the auditorium (in both plan and section)
- the flat floor in the stalls
- the cubic volume of the hall (in excess of 11,000 cubic meters)
- the solid, acoustically reflective materials used on the majority of surfaces in the space
- the convex coves at the perimeter of the ceiling
- the convex walls on either side of the stage

Modifications to any of the above features should be avoided. Any program of renovation works should be undertaken only under the direction of an experienced acoustical professional.

Scope of Study

Akustiks was engaged to complete an acoustical survey of The Colosseum at the Watford Town Hall. This work encompassed the following tasks:

1. Conducting a physical survey of the Watford Colosseum.

2. Conducting a series of objective measurements to document the current acoustical characteristics of The Colosseum.

3. Attending a rehearsal and concert of the English Classical Orchestra to develop a subjective assessment of the acoustics.

This report documents the results of this acoustical survey.

Study Process

To complete this assessment, Paul Scarbrough of Akustiks traveled to Watford on Thursday, 25 September 2008 and was accompanied by Helen Goddard and two staff members from AMS Acoustics, Ltd. During this visit, we accomplished the following tasks:

- Attended a rehearsal of the English Classical Players
- Conducted a series of acoustical measurements in the auditorium and on stage
- Attended the Thursday evening performance of the English Classical Players

Program Use

Watford Colosseum serves as the principal performance venue for the English Classical Players. Each season, the orchestra presents a series of concerts under the aegis of the Classic Concerts Trust and Watford Musical Heritage. The Colosseum is also used regularly for concerts by the BBC Concert Orchestra. A number of other ensembles based in the Southeast have expressed interest in the space. In addition to classical music concerts, Watford Colosseum has been or is presently used for contemporary music concerts, conferences, lectures, trade fairs, product launches, discotheques, and private functions such as weddings and parties.

A Brief Note on the Significance of The Colosseum

The Watford Colosseum was designed by architect Charles Cowles-Voysey with acoustician Hope Bagenal. Since opening in 1938, many famous artists and ensembles have presented concerts on its stage or used the auditorium for recording purposes. The importance of this roster of famous ensembles and artists should not be casually dismissed. The reputation of any great hall derives as much from a storied history of performances as well as its acoustics. Some halls with less than ideal acoustics play host to the world's leading performers only by virtue of their location (Royal Festival Hall in London and Avery Fisher Hall in New York being two prominent examples). Other halls with great acoustics sometimes never develop much of a reputation because their location outside a major music capital keeps them in the shadow of better-known venues. The Colosseum combines great acoustics with a history of use by great performers, a rare and valuable asset that can be used to advantage in Watford.

Physical Description

The Watford Colosseum is a classic shoebox shaped concert hall. Its key features are as follows:

1. The hall encloses a cubic volume of approximately 11,600 m^3 and is about 22 m wide, 50 m long and 12 m tall.

2. The major materials of construction include wood paneling (over an airspace) for the lower walls, plaster on brick for the upper walls (punctuated periodically by windows), suspended plaster for the ceiling and wood flooring (with a thin carpet cover for concerts).

3. Stalls seating is on a flat floor whilst the balcony seating has a shallow rake. The stalls seating is portable and removable whilst the balcony features fixed theater seats.

4. The fixed stage is largely flat and has an area of about 166 m, which can normally be expected to accommodate a maximum of about 85-90 musicians. An original system of raked choral risers was removed from the stage some years ago. Organ chambers frame the stage on either side.

Figure 1: A general view of the interior of The Colosseum

Acoustical Character of The Watford Colosseum

The acoustical environment for orchestral and choral music in Watford Colosseum is very much in line with what one would expect from a hall of this shape and size. In summary, the hall is reverberant and features a solid bass and good clarity. The acoustical factors that give rise to these impressions are detailed below.

Acoustical Intimacy, Presence & Articulation

For non-amplified music, these qualities are governed by what are called early reflections. Early reflections are the first sounds to arrive at the listener after the direct sound arrives in a straight-line path from the performer to the listener. Reflections that arrive within 15 to 40 milliseconds of the direct sound contribute to our sense of acoustical intimacy. The relatively narrow width of the hall means that reflections from the sidewalls will arrive at most listeners within this timeframe. This gives the hall a good sense of acoustical intimacy and contributes to clarity. Figure 2 illustrates this important geometric relationship.

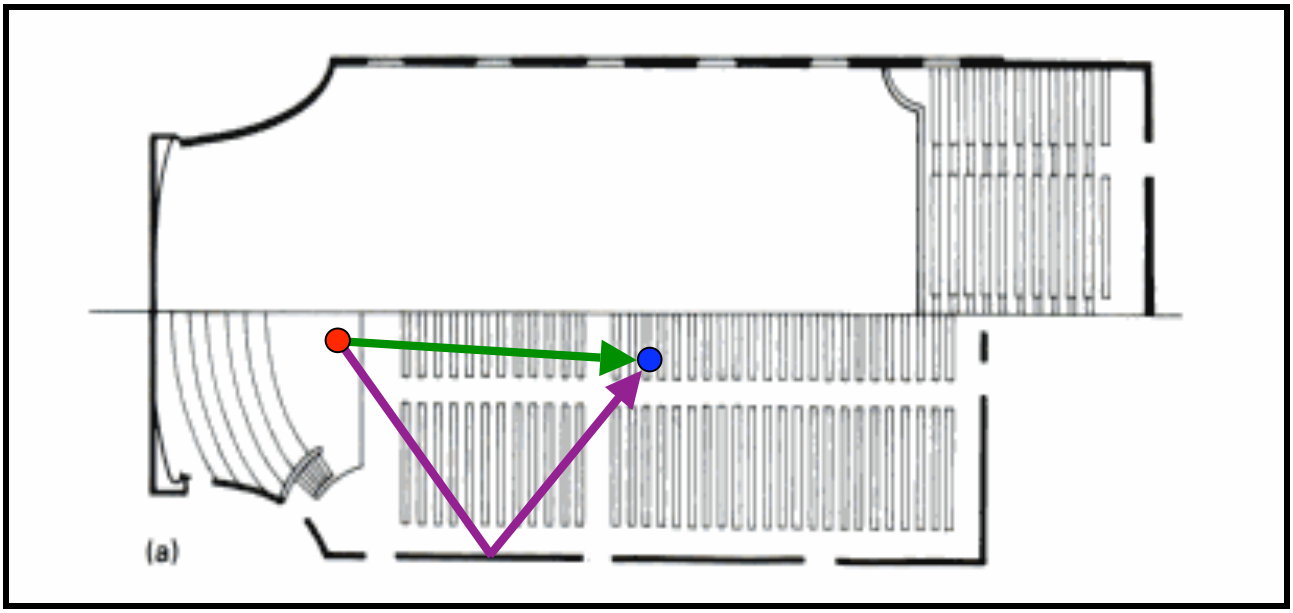

Figure 2: A plan view of the Colosseum with the balcony level at the top and the stalls level at the bottom. The red circle indicates a typical performer position on stage (in this case the orchestra leader). The blue circle indicates a typical listener in the stalls. The green arrow represents the direct sound (that which travels directly from the concert leader's violin to the listeners ear without reflecting from any surface). The path length of the direct sound is about 13 m and the sound takes roughly 38 milliseconds to travel this distance. The purple arrow represents an early reflection from the sidewalls. The path length of this reflection to the wall and back to the listener is about 23 m and the sound takes roughly 68 milliseconds to travel this distance. The difference in the travel time is about 30 milliseconds placing it well within the preferred range of 15-40 milliseconds. (Plan view of the Colosseum from *Auditorium Acoustics and Architectural Design*, Michael Barron, 1993)

Envelopment or Immersion

This quality, the impression of being completely surrounded by or immersed in sound, is governed strongly by the presence of what acousticians call lateral energy, that is sound that arrives from the sides and rear of the listener rather than from above. The solid construction of the side and rear walls of the hall gives the listener a decent sense of envelopment.

Impact

Impact is related both to the scale of a performance space and the degree to which the stage area effectively projects the sound of the performer to the audience. In halls with good impact, performers are able to create an intense and visceral experience for the audience. At 11,600 cubic meters, Watford Colosseum is nearly identical in size to the Grosser Tonhallesaal in Zurich, a concert space where orchestras are able to achieve quite good impact.

Resonance or Reverberation

Another key acoustical criterion is reverberation time. Musicians often refer to this as resonance or liveness. Reverberation is important in music because it helps to blend the various instruments in an ensemble into a single unified whole. The level of reverberant energy is also important. Fullness of sound for music is generally related to a high level of reverberant sound relative to the direct sound.

Reverberation is the time it takes a high level sound to decay 60 decibels or in lay terms the number of seconds it takes for a loud sound to decay to inaudibility. Reverberation is related to the cubic volume of a space and the amount of sound absorbing materials in that space. Raising the volume increases or lengthens the reverberation time. Adding sound absorptive material to a space decreases or shortens the reverberation time. Reverberation is also related to the geometry of space. Spaces with a rectangular geometry and long parallel walls tend to have strong reverberation. This is one reason that shoebox-shaped concert halls tend to be reverberant.

Through research and experience, preferred ranges of reverberation times and levels have come to be associated with different performance types, as outlined in the Table 1:

Activity or Program	Reverberation Time (at mid-frequencies*)	Reverberation Level (relative to direct sound)
Amplified Music & Entertainment	Less than 1.4 seconds	low
Drama & Unamplified Speech	Less than 1.3 seconds	moderate
Opera & Ballet	1.4 to 1.7 seconds	moderately high
Symphonic Music	1.8 to 2.2 seconds	high
Organ & Choral Music	2.0 to 3.5 seconds	very high

Table 1: Ranges of Reverberation Times

* Reverberation times are measured in individual octaves from low to high frequencies. A mid-frequency reverberation time is the average of the times at 500 Hz. and 1,000 Hz. octave bands. Unless otherwise noted, all references to reverberation times in this report refer to these mid-frequency average times.

Reverberation time measurements were gathered for a variety of locations throughout the hall and on stage. Table 2 presents the average of the times measured at the various locations:

Unoccupied Reverberation Times (seconds)	Octave Band Center Frequency, Hz.							
	63	125	250	500	1000	2000	4000	8000
Average of Stalls and Balcony	2.13	2.31	2.50	2.40	1.91	1.64	1.38	1.26

Table 2: Measured Average Reverberation Times for Watford Colosseum

The mid-frequency average reverberation time is 2.15 seconds in the unoccupied condition. The presence of an audience will tend to reduce this average by about 0.20 to 0.25 seconds, yielding an estimated occupied mid-frequency average reverberation time between 1.90 and 1.95 seconds. This places Watford Colosseum in the company of a number of great concert halls including Boston Symphony Hall (1.90 seconds), the Vienna Grosser Musikvereinssaal (1.97 seconds) and the Amsterdam Concertgebouw (2.00 seconds).

Diffusion

One essential characteristic of a good music space is that sound be evenly distributed throughout the listening chamber. One way to promote this is to articulate the surfaces in a room to promote good acoustical diffusion. To be effective, such articulation needs to occur at a variety of scales from larger elements (about 30-60 cm in depth) to small elements (5 to 15 cm in depth). The curving organ screens on either side of the stage and the convex coves at the edges of the ceiling provide a significant amount of larger scale diffusion in the Colosseum. There is little in the way of smaller scale articulation in the space but this lack of fine scale diffusion seems to be compensated by small areas of sound absorbing material on the face of the balcony and the open grilles into the organ chambers. This absorptive material probably helps to temper the high frequencies in the hall and keep them from becoming too brittle or harsh.

Bass Response

The time arrival and strength of later arriving, low frequency reflections govern bass response. By later arriving, we mean between 75-300 milliseconds after the direct sound from the stage. By low frequency, we refer to the octave bands at and below 250 Hz. This is the range of sounds produced by the bass instruments, such as the double bass, cello, tympani and bass drum. The strength of bass reflections is governed by how massive and stiff the boundary surfaces are in a concert hall.

The bass response in the Colosseum seems reasonably strong subjectively and the measurements indicate that the reverberation times in the 250 and 125 Hz. octave bands are generally high although not higher than the mid-frequency average. At 63 Hz. the reverberation time is significantly weaker than at 125, 250 and 500 Hz. This may be due to the lightweight wood paneling on the lower sidewalls, which may absorb some deep bass sound and the windows, which may allow some bass sound to escape. Further study of this condition is advised to determine whether improvements in bass response are warranted and possible.

Late Reflections or Echoes

Late reflections or echoes can disturb the listeners' experience by smearing the sound coming from the stage. A review of the impulse responses (a graphical representation of the acoustical signature of a space) did not reveal the presence of any problematic reflections. The following figure illustrates one such impulse for seat Y-21.

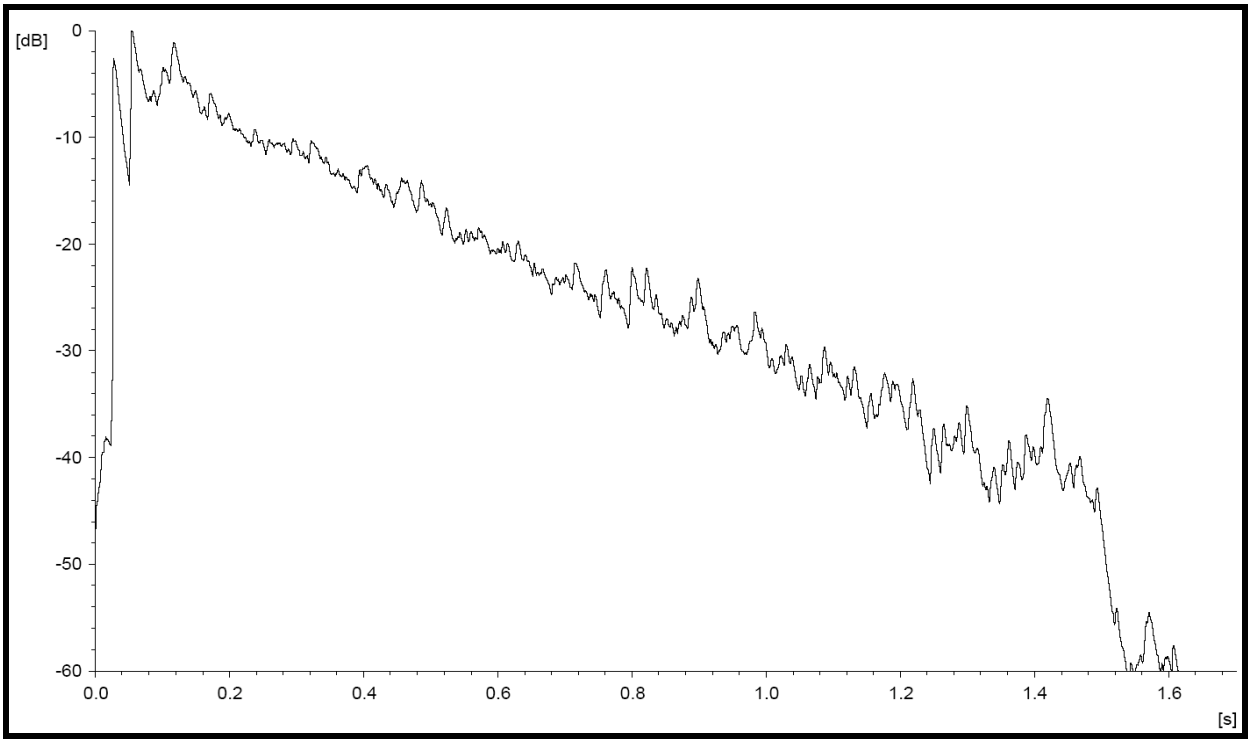

Figure 3: An integrated impulse response for seat Y-21. The vertical axis is the sound level in decibels and the horizontal axis is time in seconds. Note that the decay is even and the individual peaks comparatively close together in time. This means that the sound will be perceived as a smooth decay and be judged free from echoes.

Background Noise & Sound Isolation

Background noise is the term acousticians use to refer to the continuous, low level of sound that is present in almost any environment. Performance spaces are typically among the quietest interior spaces built. In fact, when new performance halls are built or existing ones renovated, careful attention is always given to the exclusion other unwanted sound from the space. Silence is important because it is often the quiet moments in a performance that communicate the most emotion and tension. When a space is silent, the difference between the loudest sounds and the softest ones is increased, giving the performer a wider range of dynamic expression.

Generally speaking, the Watford Colosseum is reasonably quiet but not silent. Noise from the building systems and from the exterior does contribute to the ambient environment inside the Colosseum. An effort to address these sources of intrusive noise is advisable.

Measurement Equipment & Process

The objective measurements were conducted using the following equipment and process:

1. The sound sources for the measurements included a dodecahedron loudspeaker and a device for firing blank cartridges. These are shown in Figures 4 and 5.

Figures 4: Dodecahedron speaker

Figure 5: Blank Cartridge Firing Device

2. The recording device was a Bruel & Kjaer binaural dummy head microphone.

Figure 6: Binaural dummy head microphone

3. A swept sine wave signal from a commercial acoustic analysis software package (Dirac) was used as the test signal for the dodecahedron speaker.

4. The binaural dummy head recorded both the swept sine wave signals and the impulses generated by the blank cartridges onto digital recording media. The binaural dummy head was moved to positions in the stalls, in the balcony and on stage.

5. The binaural dummy head was also used to sample the background noise in the space.

6. The various recordings were input into the Dirac software package for additional analysis.

Subjective Assessment

The concert on 25 September 2008 also offered the opportunity to conduct a subjective assessment of the acoustics of the space under conditions of actual use. The program for the concert comprised the following works:

Beethoven – Overture *Fidelio*
Beethoven – *Violin Concerto*
Brahms – *Symphony No. 3*

The program was conducted by the Artistic Director of the English Classical Players, Jonathan Brett. The soloist for the concerto was violinist Alëna Baeva.

During the rehearsal, the acoustics were very live. The rehearsal offered the opportunity to sample the acoustical quality in a wide variety of locations. Generally speaking, the sound quality in the Colosseum was found to be quite uniform.

For the performance, I was seated in the first row of the balcony toward the right side of the house. This was an excellent seat with a clear view of the stage. From this location, the acoustics in the Colosseum were rich, warm and clear. The sound of the orchestra was well blended and had a cohesive, integrated quality. The balances between sections were quite good. Communication among soloist, orchestra and conductor appeared to be comfortable. The conductor was able to achieve a good balance between the soloist and orchestra. The sound of the soloist was rich and did not seem in any way forced.

With the audience present, the reverberation observed during the rehearsal was toned down but not to an unpleasant degree. The orchestra was able to fill the room easily and to have a dramatic impact when the score called for it.

The nature of the acoustics makes the Colosseum especially well suited to the works on this program. The modest scale of the space and its acoustics will mean that it will generally be best for music of the Baroque, Classical and Early Romantic eras. The larger ensembles associated with the music of the late Romantic and Modern eras will more easily overpower the space, requiring the conductor to avoid this problem.

Conclusions

Overall impressions of the acoustics of Watford Colosseum are highly favorable. Subjectively the acoustics of the space compare favorably to other great concert rooms in Europe and America, impressions that are supported by an analysis of objective measurement data collected in the space. The acoustical qualities observed in the Colosseum are consistent with the classic shoebox geometry of the space and its major dimensions and other features.

The modest scale of the Colosseum is its chief limitation. The cubic volume of the auditorium (approximately 11,600 cubic meters) makes the Colosseum more like the Tonhalle in Zurich than the Musikvereinssaal or the Concertgebouw in Amsterdam. This smaller cubic volume contributes to the sense of impact that performers can create in the hall but it also makes it more likely that large ensembles will overpower the space. This suggests that the hall is perhaps best suited to music of the Classical and early Romantic eras. The larger ensembles that are characteristic of the later Romantic period can be presented successfully in the space provided the conductor employs an appropriate approach to shaping the dynamics of the performance.

Any future redevelopment of the Colosseum should be undertaken with careful oversight from a knowledgeable acoustical professional. It is essential that the features that produce its exceptional acoustical character not be inadvertently changed. For example, one of the features that contributes to the reverberant quality of the hall is the flat floor configuration in the stalls. Any move to create raked seating in the stalls will significantly increase the sound absorbing properties of the audience and sharply reduce the reverberation time in the space. Likewise, an updating of the building's systems can create opportunities to reduce the amount of sound that these systems introduce into the Colosseum and thereby give performers a greater range of dynamic expression.

Acknowledgements

I would like to acknowledge the assistance of Helen Goddard and AMS Acoustics, Ltd. in this assessment of the acoustics of the Watford Colosseum. AMS Acoustics supplied the measurement equipment and staff necessary to complete the objective measurements of the acoustics in the Colosseum. It would not have been possible to organize the measurements on such short notice without their assistance.