ACOUSTICS OF SIX HISTORIC CINEMAS IN NEW SOUTH WALES, AUSTRALIA

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Historic cinemas, some of which were built before sound film, are often heritage listed, placing significant limitations on architectural modifications. Such cinemas may face challenges in complying with modern audio and acoustical standards and recommendations. This paper outlines the acoustical conditions in selected historic cinemas of New South Wales, Australia. Background noise, reverberation time, speech intelligibility and impulse response measurements were made, and the room and sound system configurations were noted. Deviations from modern acoustical standards were observed. Room size, interior finishes, and the presence of galleries sometimes pose challenges for acoustical performance.

1 INTRODUCTION

Thorne [1] has comprehensively documented Australia's historic cinemas in terms of their heritage features, with a listing of some 2040 venues in New South Wales that have screened films regularly, at least for a time. This paper considers the acoustical state of six of these historic cinemas, all of which are heritage listed for their historical, social and/or aesthetic values. Some are exclusively or mainly used as cinemas, while others have multiple uses. Of the six cinemas in this paper, all were built before the advent of television, and most of them are in the Art Deco style, popular in 1930s architecture, in an era when going to the movies was 'an occasion to dress for' [1]. The cinemas are Dungog community hall and cinema (which opened as a cinema in 1930), Grafton's Saraton Theatre (opened as a cinema in 1926), Mudgee's Regent Theatre (opened as a live performance theatre in 1925), Randwick's Ritz Theatre (opened as a cinema in 1937), Scone's Civic Theatre (opened as a cinema in 1938) and Sydney's State Theatre (opened as a cinema in 1929). The interior forms of these are illustrated in Fig. 1.

The development from the original 'talkies' through stereophonic to multi-channel surround sound formats has seen increasingly stringent acoustical requirements, which may pose considerable challenges for theatres constructed prior to film sound. One source of acoustical specifications for modern cinemas is the Society of Motion Picture and Television Engineer's standards [2, 3], which are developed further in Dolby's published guidelines [4]. We use these guidelines in comparison with our measurements made in the six cinemas. The main assessments are concerned with background noise levels and spectra, reverberation time, and speech intelligibility. The acoustical effects of some architectural features are also considered in this paper. This brief paper presents just a summary of our results.

2 APPROACH

Impulse response measurements were obtained in each auditorium. For this an omnidirectional loudspeaker was positioned just in front of the screen, in the centre (the cinema loudspeakers were not used). An omnidirectional measurement microphone was positioned at a height of 1.2 m, and placed at numerous seat positions. The selected

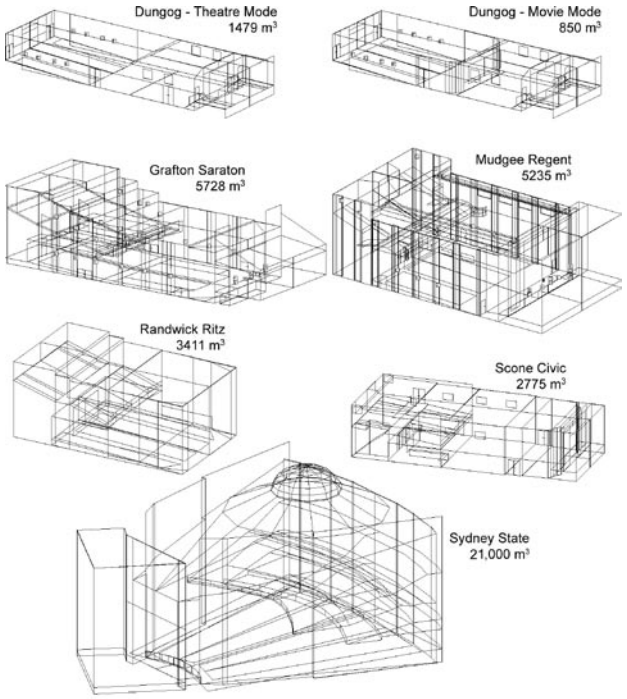

Fig. 1. Models of the cinema interiors.

seat positions were at multiples of 5 m from the loudspeaker, along the centre line of the theatre, as well as in at least one parallel line 5 m to the side. In the State Theatre, measurement positions were 0 m, 5 m, 10 m and 15 m from the centre line (yielding 33 receiver positions). Impulse response measurements were made using the maximum length sequence (MLS) technique [5]. Reverberation times and echo patterns were derived from these impulse responses. Objective speech transmission index (STI) measurements were also taken at most of the receiver positions used for the abovementioned impulse responses, with the MLS signal filtered to match the long term average speech spectrum [6]. STI yields a value between 0 and 1 representing speech intelligibility, determined from modulation transfer functions from source to receiver (0.45-0.6 is classed as

'fair', 0.6-0.75 is classed as 'good', and 0.75-1.0 is classed as 'excellent', although 'excellent' results are uncommon in room acoustical measurements) [7]. Background noise measurements for ambient noise levels were carried out integrating over 60 second periods.

3 MEASUREMENTS

3.1 BACKGROUND NOISE

The steady state background noise level in cinemas should be below NC 25, with NC 30 being the worst case acceptable in modern recommendations [2]. The background noise due to intermittent events should not exceed NC 35. With four of the cinemas in quiet country towns, in most cases the steady state noise floor was low enough to satisfy the recommendations, at least when the heating, ventilation and/or air conditioning (HVAC) systems were not operating. In some cases the building relied on natural ventilation, and ceiling-mounted fans and/or wall-mounted heaters could be used.

The HVAC systems produced considerable noise at two of the cinemas (Dungog and Scone) where the noise floor was otherwise acceptable (NC 22 and NC 23 respectively). In Scone, the cause was an installed ducted ventilation system that makes no concessions for acoustic design. The effect of this was most significant in the ground level auditorium (NC 37), but fortunately the cinema audience is restricted to the gallery (NC 29). In Dungog, simple fan-forced heaters produced considerable noise. They were mounted on the rear wall, and a decision between noise and cold could be made in winter months. Not only was the level of the heater noise (NC 44) very high, but the noise was characterised by a 2 kHz octave band peak, which more sophisticated noise rating methods treat as a severe spectral imbalance (e.g., Room Criterion mark II rates the noise as 44(HF), QAI = 19).

Intermittent noise levels could be a problem in some of the quiet country towns, with passing trains or road traffic significantly affecting the background noise level, although this intrusion of road traffic noise in to the structure may have been less severe when the cinemas were opened. In many cases doors are lightweight, are not sealed, and the buildings rely on natural ventilation, so that sound can easily enter the buildings. In Grafton, a bus stop was located directly outside the cinema entrance, so that the diesel engines introduced sustained noise for periods of time. In Mudgee, an automotive mechanic works next door, generating noise such as hammering during the day (which is not a problem for evening screenings).

3.2 REVERBERATION TIME

Dolby recommends cinemas to have reverberation times as short as possible, within reason, and a spectral profile flat at mid frequencies, potentially increasing at low frequencies and decreasing at high frequencies. A large volume room is permitted to have a longer reverberation time than a small room, but the mid frequency reverberation time should not exceed 1.5 seconds (applying to a volume of approximately 30,000 m^3). More generally, the optimum reverberation time for auditoria depends on the purpose of the room, and somewhat longer reverberation times are recommended for drama theatres of equivalent volume [8]. With cinemas the prime requirement is clear direct sound from the loudspeakers because all the required effects of spatial impression and reverberance are added at production stage, calling for low reverberation times. The desired concert hall effect of strong early lateral reflections to increase the apparent source width [9] becomes a hindrance. Of course, great acoustic absorption demands greater electro-acoustical power to reach the high sound pressure levels at maximum audio system output required for digital film sound.

Measured octave band reverberation times are shown in Figure 2 (1/3-octave band data are not presented here for succinctness). Recommended mid-frequency reverberation times for these cinemas range between 0.3 and 1.3 seconds depending on the room volume. Two of the cinemas met the design criterion (the Randwick Ritz and the Sydney State cinemas), not only in terms of the mid-frequency reverberation time, but also the variation of reverberation time with frequency. However the rural cinemas tended to have long reverberation times, especially in the mid frequency range. The presence of the large areas of exposed plaster on the walls, and in some cases the original leather upholstered seating, are largely responsible for these long reverberation times.

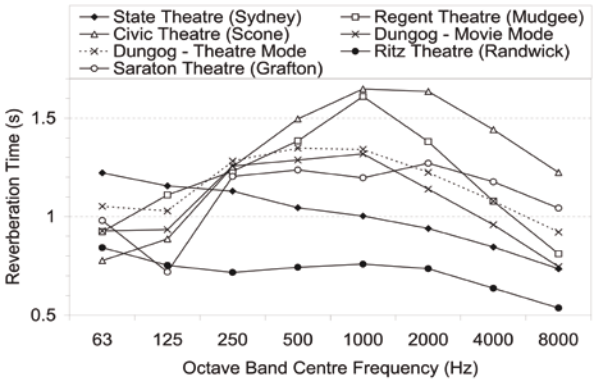

Fig 2. Measured spatially averaged reverberation times (T30) for the six cinemas.

Dungog cinema, which also functions as a community hall, is a long hall, divided into two sections when used in cinema mode (Fig. 1). The screen lowers from the ceiling, and plush curtains are used to create an intimate cinema space within an otherwise excessively long room. The three main loudspeakers are positioned behind the screen (which divides the room), with plywood wings to reduce the acoustic effect of the room's remaining volume. However, the introduction of these features actually makes little difference to the reverberation time, as shown by Fig. 2. The room meets the reverberation time requirements for a drama theatre (1.2 s, measured with a source on the stage, with the room in theatre mode), but has more than twice the recommended mid-frequency reverberation time for a cinema of its volume (0.3-0.5 s for the cinema volume, or 0.4-0.6 s based on the full room volume). Nevertheless, with all of the seats relatively close to the loudspeakers, reverberation is relatively innocuous.

Grafton's Saraton Theatre is used for live performance as well as cinema screening, as it is the sole major auditorium in the town. Because it is quite voluminous, a fairly long reverberation time (for a cinema) is recommended (0.6-0.9 s) – and the theatre comes close to meeting this. This is also close to the 1.25 s reverberation time that is recommended for drama theatre use. The dip in the low frequency reverberation times (Fig. 2) is mainly due to the existing original wooden floor – a feature in other cinemas tested. Even

though this might result in lack of warmth for live performance [8, 9], for cinema acoustics this is a benefit (being in the recommended range for cinemas and so avoiding a 'boomy' or 'muddy' bass).

Upon entering the Mudgee Regent cinema, the art deco interior, large stage and high lofty ceiling make a striking impression (Fig. 4). It has the largest Cinemascope screen in NSW, which nevertheless seems relatively small in this spacious cinema (similar in volume to Grafton's Saraton, but shorter and taller). The large volume and extensive plasterwork result in long reverberation times. For live performances the mid-frequency reverberation times are longer than recommended (1.25 s recommended), and so are substantially longer than recommended for a cinema of this volume (0.6-0.9 s). Similar to the Grafton Saraton and Randwick Ritz, the gallery has more absorptive surface materials than the ground level auditorium. The auditorium has a wooden floor which is the likely reason for the short reverberation times at low frequencies. When we visited this cinema, the audience was restricted to the gallery.

Fig 3. View of the interior of Dungog Cinema in movie mode

The Randwick Ritz is a remarkably well-adjusted theatre in acoustical terms. It has plush modern seating. The floor is carpeted with modern cinema carpeting, and drapery is used around the side and rear walls. Nevertheless, significant heritage architectural features in the front section of the cinema visually dominate the interior. Our measurements show the cinema's reverberation time spectrum to be a near-exact match to that recommended for a cinema of this volume (a mid-frequency reverberation time of 0.5-0.8 s is recommended).

The Civic theatre in Scone has similar proportions and volume as the Ritz, but when we visited, it had less absorption than its original state because seats had been removed from the main floor area. The original leather cinema seats remained in the gallery. The main wooden floor was exposed, and had ten double couches with wooden coffee tables, and a bar. The ground floor of the theatre was used mainly for social functions and gatherings with the occasional live performance as entertainment for these functions. While the recommended mid-frequency reverberation time for a cinema is 0.5-0.8 s, or 1.2 s for a theatre, our measurements yielded values exceeding 1.5 s at 1 and 2 kHz, contrasting with little reverberation in the low octave bands. Because of its similarity to the Ritz Randwick, the prospect of meeting the acoustic recommendations for cinemas should be high.

The State Theatre (Fig. 5) has acoustics that suit its purpose well, especially considering that it is such a large theatre. The auditorium is mainly used for amplified performances, meaning that a longer reverberation time is not required for theatrical productions. It also hosts the annual Sydney International Film festival. The reverberation time criterion recommended by Dolby (0.9-1.3 s) is satisfied by the cinema.

Fig 4. View of the interior of Mudgee's Regent Theatre.

3.3 SPEECH TRANSMISSION INDEX

Speech intelligibility factors depend greatly on reverberation and ambient sound level. The recommended reverberation times and background noise limits of the Dolby guideline would also help to achieve the desirable high speech intelligibility. It was possible to experience a film screening at one of the cinemas (the Regent theatre - Mudgee), and a private screening of film trailers at two others (Grafton's Saraton and the Dungog cinema). With the audience restricted to the gallery level at Mudgee, the subjective assessment of all who watched the movie was of poor speech intelligibility. This is reflected by STI values ranging between 0.55 and 0.61, which are overwhelmingly determined by the reverberation (rather than background noise). This cinema's long mid-frequency reverberation time, coupled with the distance from the screen, are the primary reasons for lack of clarity.

It is instructive to compare Mudgee's Regent Theatre with Dungog's cinema, as they exceed the recommended reverberation time by a similar ratio, but the subjective impression of listening to trailers in the Dungog cinema was very positive. When in movie mode, the Dungog cinema's STI ratings range from 0.67 to 0.70, which is substantially better than the Mudgee ratings. Like Mudgee, the STI values at Dungog are controlled by reverberation time, but the ratings are higher because the reverberation times are somewhat shorter in absolute terms, and the distance between the loudspeakers and audience is much shorter.

The State Theatre had a wide range of STI ratings (from 0.57 to 0.73), some of which were influenced more by discrete echoes than reverberation. Features contributing to these echoes are discussed in the next section.

The Randwick Ritz yielded the best STI ratings (from 0.71 to 0.76), with the lower ratings under the gallery. Grafton's Saraton theatre and Scone's Civic Cinema shared similar STI values - between 0.57 and 0.61. In both cases the galleries created acoustical difficulties in maintaining speech intelligibility

4 ARCHITECTURAL FEATURES AND THEIR EFFECTS

Of the six cinemas measured, five have galleries. Galleries are discouraged in recommendations, because it is very difficult to direct the front loudspeakers (which are behind the screen) into the areas

both under and above a gallery. Barron [10] recommends that depth of a gallery overhang be less than the height, at least in a concert hall, and a similar rule-of-thumb might be applied to cinemas, where a similar problem of maintaining loudness and definition from a frontal source applies. Apart from Mudgee's Regent Theatre (H/D of 1.3), the height-to-depth ratios are substantially less than suggested by Baron for concert auditoria (0.3 for Grafton, 0.4 for Scone and 0.5 for Randwick). Impulse responses measured deep under the galleries of Grafton and Scone are characterised by a weak direct sound relative to the reverberant decay.

Galleries can also introduce distinct reflections and echoes. In both Scone and Grafton, seats in the stalls in front of the gallery received substantial reflections from the face of the gallery, and in some cases this reflected sound was stronger than the direct sound.

An interesting effect occurs in the State Theatre, which has a series of domes in its ceiling. These focus the sound from the centre of the stage onto the rear centre seats of the upper gallery, and the resulting reflections are substantially stronger than the direct sound. The sound from the stage is surprisingly loud at this centre rear position, reminiscent of the whispering gallery effect.

Fig 5. View of the interior of Sydney's State Theatre, showing the measurement source on the stage.

5 CONCLUSIONS

This paper compares acoustical characteristics of six historic cinemas with recommended values for the demands of modern digital surround sound. Cinemas generally meet the background noise recommendations, at least when their HVAC systems are not operating. However, there were some cases where HVAC caused excessive noise. Noise intrusion from external sources was sometimes a problem. Reverberation times were generally excessive in the country cinemas, but met recommendations in the city cinemas.

This survey raises the question of whether meeting acoustical recommendations is necessary in historic cinemas – or whether a 'historic' sound might be considered a positive feature of a cinema. Noise generally is undesirable in cinemas – the intrusion of traffic noise or hammering certainly would be distracting, but the crackling noise of film projectors may be tolerated and even add to the enjoyment of the experience. A steady-state noise from HVAC might be useful in masking an intractable intermittent exterior noise problem in quiet sections of a film. It is also possible that reverberant characteristics matching the grandeur of a large theatre could be desirable so long as intelligibility is maintained.

Modern cinemas are often neutral environments, with drapery as the main architectural feature. By contrast, the historic cinemas in this study mostly have significant architectural appeal in their interiors, which gives the visitor a richer experience than visiting a fully draped room (the exception is Dungog, which is a heavily draped room when in cinema mode). The renovation of Randwick's Ritz cinema balances drapery with architectural features, meeting modern acoustical recommendations. Nevertheless, such an approach in a large volume theatre such as Mudgee's Regent would need to be done carefully to avoid detracting from the visual appeal of the room. The State Theatre has the fortune of having a large upholstered audience area and a perforated ceiling, and so meets reverberation requirements for a cinema of its size perhaps by coincidence.

The measurements presented in this paper were made in 2003, and the acoustical conditions in the cinemas may have changed in subsequent renovations.

6 ACKNOWLEDGMENTS

The authors are very grateful to Jeff Boltze, Angelo Notaras, Ken Reeve, Des Stibbs, Elizabeth and Bill Suttor, and Jack Ziade for allowing measurements to be made in their cinemas. They are also thankful to those who assisted with the measurements, namely Bill Antram, John Bassett, Young Ji Choi, Ernesto Estivill, Angelo Farina, Fergus Fricke, Megan Kwak, Andy Nguyen, Riduan Osman, Ken Stewart, Jingfeng Xu and the 2003 Audio Systems and Measurement class from the University of Sydney's graduate Audio and Acoustics program.

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