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A PRELIMINARY TRAFFIC NOISE INVESTIGATION IN AN ACOUSTICALLY UPGRADED DWELLING

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ABSTRACT

A preliminary study was carried out to investigate the acoustical effectiveness of residential multiple occupancy dwellings located on North East Road, Adelaide which were designed to reduce the adverse impact of traffic noise. Noise measurements were taken both at night and day.

Indoor and outdoor L_{Aeq}, L_{A10}, L_{A90}, L_{A01} and L_{Amax} were obtained simultaneously every 15 minutes over a six day period. The investigation determined both the 'mean' outdoor and internal noise and the resulting 'mean' outdoor to indoor noise attenuation for each noise descriptor. The internal noise levels were compared with selected traffic noise criteria.

It was found that the resulting amenity within the acoustically upgraded dwelling was superior to conventional construction dwellings. Resulting internal noise levels generally satisfied the Shire of Hornsby Building Code criterion. However OECD criteria based on the L_{Aeq} and the L_{Amax} noise level were exceeded.

1.0 INTRODUCTION

A study was undertaken to investigate the effectiveness of acoustically designed multi-occupancy home units at the St Andrews Close development located along side North East Road, Walkerville, Adelaide. The development was part of the South Australian Department of Housing and Urban Development (DHUD) "Green Street Program", a program aiming to promote higher standards of design in urban developments. The project was described as a "Demonstration Estate" and was supported through Commonwealth funding, via DHUD, in providing funds for architectural and acoustic design fees. The estimated cost of the acoustic measures and "noise resistant construction" was $8,750 per unit (DHUD, August 1994) or approximately 4.4% of the purchase price.

The information used in this paper has been taken from a Third Year Research Project undertaken by the Flinders University of SA (Bukutu, 1995) which was supported and directed with the assistance of the Environment Protection Authority. The FUSA study was based on a report (Carter, Ingham and Tran, 1992) which obtained continuous night time noise measurements within bedrooms and at facades of dwellings of standard construction located along Pennant Hills Road, Sydney, NSW. Due to time and resource constraints, the FUSA study considered less dwellings and less days of measurements. Further, the FUSA noise measurements were collected at 15 minute intervals for the entire 24 hour period whereas the Sydney study obtained measurements over 20 second intervals and then averaged them to determine the values over 15 minute intervals during the night-time (10pm and 7am) period.

The purpose of this paper is threefold:

- to provide an indication of the acoustical effectiveness of acoustically designed dwellings,
- provide some insight into the relationship between noise descriptors for both day and night-time periods, and
- to ascertain whether stated noise criteria are satisfied or not.

2.0 METHOD

2.1 STUDY LOCATION AND TRAFFIC VOLUME AND COMPOSITION

Figure 1 shows an aerial view of the St Andrews Close development. Acoustic measures within the units adjacent to North East Road include fixed double glazing for windows facing the road; double leaf plasterboard ceilings to the first floor; locating the stairs and 'wet areas' to provide sound buffers to noise sensitive rooms; acoustic door seals, silicon sealing of windows and door frames and wall cavities. The windows facing away from the main road (including within bedrooms) were openable. A roadside barrier was also installed to reduce noise to the lower level of these units. An unbroken barrier formed by the two-storey units closer to the road (except for the one entrance) reduces noise to the units to the rear of the development. The units to the rear are of standard building construction.

The information documented in this paper is based on data obtained from one of the acoustically upgraded units adjacent to the main road. Figure 2 shows the layout of a typical unit in the development. Internal noise measurements were taken in Bedroom 2. The unit was unfurnished at the time of the measurements except for carpet in the living spaces, including the bedrooms.

North East Road, which is adjacent to the development, has an estimated daily traffic flow of 40,000 vehicles, of which 21,200 are city bound and 18,800 are north east bound. The commercial vehicle proportion of the total traffic is 3.8%. The peak hour, two-way, traffic flows are:
7.45am-8.45am 3980 vehicles (2.1% commercial vehicle content) with 82% city bound;
4.45pm-5.45pm 4240 vehicles (2.2% commercial vehicle content) with 72% north east bound. (Department of Transport, 1993).

The closer lane of traffic to the measurement site is the city bound.

2.2 DATA COLLECTION

Measurements were undertaken simultaneously by manually synchronising two noise logging units.

The outdoor noise measurements were obtained using an ARL Environmental Logger EL-215. It was positioned one metre in front of the wall exposed to the traffic and in full view of the traffic (that is, the line of sight between the microphone and traffic flow was unobscured by the roadside barrier). Calibrations were made prior to the commencement of measurements.

Indoor noise measurements were obtained in the most noise-exposed bedroom using an RTA Sound Logging Meter. The microphone was positioned one metre from the window at a height of 1.2 metres above floor level.

The L_{Aeq}, L_{Amax}, L_{A01}, L_{A10}, and L_{A90} noise data were logged at 15 minutes intervals over a six day period including a full weekend.

2.3 DATA REDUCTION

The data obtained amounted to 562 values for each noise descriptor, one for each 15 minute interval. These interval data were combined to 96, 15 minute (ie a 24 hour period) intervals by obtaining the mean of the corresponding 15 minute interval data for each day. For example, the 15 minute interval 9am to 9.15am for each day was averaged to obtain a mean value for the 9am to 9.15am interval, and similarly for each of the remaining 95, 15 minute, intervals. All averaged data is subsequently referred to as 'mean' data. The statistical noise data (L_{Amax}, L_{A01}, L_{A10}, and L_{A90}) were arithmetically averaged and the L_{Aeq} was logarithmically averaged using the formula below:

$$L_{Aeq} = 10 \text{ Log}10[(1/N) \sum 10^{(LAeq,Ti/10)}]$$

where LAeq,Ti is the L_{Aeq} for the i[th] 15 minute interval.

The 15 minute 'mean' data was further reduced to provide a single average 'mean' value for the 24 hours (i.e., an arithmetic average of the 96 mean, 15 minute, values), the 'daytime' period (defined as 7am to 10pm, consisting of 60 mean, 15 minute, values) and the 'night-time' period (defined as 10pm to 7am, consisting of 36 mean, 15 minute, values).

3.0 RESULTS

3.1 MEAN OUTDOOR AND INDOOR NOISE LEVELS

Figures 3 to 7 depict the 'mean' outdoor and indoor noise levels for each noise descriptor over the 24 hour period.

The figures show that outdoor L_{Amax} and the L_{A01} remain relatively constant over the 24 hour period. Both the L_{A90} and the L_{A10} exhibit sensitivity to reduced traffic flows at night, particularly so for the L_{A90}. The variation in L_{Aeq} lies in between these two groups. Table 1 describes the maximum and minimum 15 minute outdoor 'mean' noise levels for each noise descriptor as well as the average 'mean' outdoor noise levels for the 24 hour, the daytime and the night-time periods.

Table 1 - Outdoor Maximum, Minimum 'Mean' and Average 'Mean' Noise Levels

Measure	Noise Descriptor				
	L_{Aeq}	L_{A10}	L_{A90}	L_{Amax}	L_{A01}
Maximum 24hour 'Mean'	67.5	68.4	56.7	82.7	75.3
Minimum 24 hour 'Mean'	55.6	53.4	35.6	75.0	67.2
Maximum 24 hour 'Mean' difference	11.9	15.0	21.1	7.7	8.2
24 hour Average 'Mean'	63.1	63.5	47.9	78.7	71.1
Daytime Average 'Mean'	64.2	66.4	52.1	79.0	72.1
Night-time Average 'Mean'	59.9	58.8	40.8	78.2	69.4

The indoor noise levels for all descriptors show minimal variation between daytime and night-time periods. The range of 'mean' values for all noise descriptors were within 6 dB(A) for both the 24 hour period and the night-time period. Since the internal noise levels do not increase/decrease proportionately with outdoor noise levels this indicates the effectiveness of the acoustical design in attenuating traffic noise. The Sydney study investigating conventional design housing (Carter et al 1992) showed much greater indoor noise level variability during the 10pm to 7am period, ranging up to 14 dB(A) depending on noise descriptor. This finding is not surprising given that the measurements were obtained with windows slightly open (up to 15 cm open). Table 2 shows the maximum and minimum 15 minute 'mean' noise levels over a 24 hour period, and the average 'mean' noise levels during the 24 hour, the daytime and night-time periods.

Table 2 - Indoor Maximum, Minimum 'Mean' and Average 'Mean' Noise Levels

Measure	Noise Descriptor				
	L_{Aeq}	L_{A10}	L_{A90}	L_{Amax}	L_{A01}
Maximum 24hour 'Mean'	37.5	39.5	34.5	51.2	45.4
Minimum 24 hour 'Mean'	33.8	33.9	33.0	44.7	38.8
Maximum 24 hour 'Mean' difference	3.7	5.6	1.6	6.6	6.6
24 hour Average 'Mean'	35.6	36.9	33.4	47.6	42.2
Daytime Average 'Mean'	36.0	37.9	33.4	47.9	42.9
Night-time Average 'Mean'	34.7	35.1	33.4	47.1	41.1

3.2 'MEAN' OUTDOOR TO INDOOR NOISE ATTENUATION

Figures 8 and 9 depict the differences between 'mean' outdoor and corresponding 'mean' indoor noise levels for each 15 minute period and for each noise descriptor. The data shows that the L_{Amax} and L_{A01} noise reduction is relatively constant throughout the 24 hour period. The noise reduction for L_{A90} is very dependant on traffic flow, as is the L_{A10} but to a lesser extent. The L_{Aeq} results are in between these two groups.

The average 'mean' noise reductions achieved for each noise descriptor for the night-time, daytime and 24 hour period are provided in Table 3. Corresponding data from the Sydney study (Carter et. al., 1992) for conventional design homes (windows closed) is also provided.

Table 3 - Average 'Mean' Outdoor to Indoor Noise Attenuation

Period of Day	Noise Descriptor				
	L_{Aeq}	L_{A10}	L_{A90}	L_{Amax}	L_{A01}
24 hour Average 'Mean'	26.9	26.7	14.5	31.1	28.9
Daytime Average 'Mean'	27.5	28.5	18.7	31.2	29.2
Night-time Average 'Mean'	24.5	23.7	7.4	31.1	28.3
Sydney Study, Night-time mean (Carter et al., 1992)	21.5	23.7	12.1	23.1	23.7

The sensitivity of the resulting noise reductions to traffic flows is evident when considering L_{A90} descriptor and L_{A10} to a lesser extent. However, L_{Amax} 'mean' noise reductions of around 31dB(A) are consistently achieved from the design over the entire 24 hour period. This is some 8 dB(A) better than the reduction expected from conventional design homes.

Noteworthy in Table 3 is the average 'mean' night-time L_{A10} noise reductions for the acoustically designed dwelling being equal to the observed L_{A10} noise reduction for conventional design houses, and further, the L_{A90} for 'acoustic dwelling' being almost 5 dB(A) less than that observed for conventional design dwellings. This is not to say that the conventional design dwellings were acoustically superior. Rather, it could be suggested that the "noise floor"(i.e., the minimum achievable internal noise level) is being reached more often in the acoustically designed dwelling. This is indicated by the low internal noise levels achieved and relatively lower variability of the internal noise levels during the night-time period.

3.3 INTERNAL NOISE CRITERIA

South Australia does not have an uniform standard for internal noise criteria for new residential developments, however, some local councils have adopted within their Development Plans the requirements specified within the Shire of Hornsby Building Code (Hornsby Shire, 1980). The Code requires the $L_{A10,20minute}$ not to exceed 40dB(A) with windows closed, during 6pm-8pm on Monday, Tuesday or Wednesday. Conventionally designed dwellings (Carter et. al., 1992) did not meet this standard except when double glazing had been used. For the acoustically designed dwelling, and based on a 15 minute measurement period only, the standard was occasionally exceeded by at most 2 dB(A), however, the standard was normally achieved. For example, the maximum 'mean' L_{A10} noise level during 6pm and 8pm was 38.5dB(A).

The Organisation for Economic Co-operation and Development (OECD, 1986) recommended internal noise criteria of L_{Aeq} not exceeding 35dB(A) and a L_{Amax} preferably not exceeding 45 dB(A) and not more than 50dB(A). The OECD criteria assumes a single event analysis and hence is not directly comparable to the 'mean' or average 'mean' data provided in this paper. Nonetheless, the 24 hour average 'mean' L_{Aeq} for the acoustically designed dwelling was 35.6dB(A), the night-time average 'mean' was 34.7dB(A). The maximum internal 'mean' noise levels were generally between 45dB(A) and 50dB(A), hence not satisfying the recommended 45dB(A) criterion, although meeting the more lenient standard of 50 dB(A).

Consideration of single event analysis was briefly considered. Single event analysis is assumed to be the maximum noise level measured in a 15 minute interval, and the L_{Aeq} for a 15 minute interval. Hence in the indoor noise data set, there are 562 single event data for both the L_{Aeq} and L_{Amax}. Table 4 describes the percentage of the single events which were below a range of L_{Aeq} and L_{Amax} cut-points.

Table 4 - Percentage of single events below L_{Aeq} and L_{Amax} cut-points

Cut-Points	% single events under specified cut-points (number of single events)
L_{Aeq}	
less than 35dB(A)	51% (167)
less than 40dB(A)	73% (410)
less than 45dB(A)	96% (537)
L_{Amax}	
less than 45dB(A)	35% (286)
less than 50dB(A)	99% (559)
less than 55dB(A)	100% (562)

Hence, the L_{Aeq} for the acoustically designed dwelling was below 35dB(A) for 51% of the total measurement period and below the 40dB(A) cut-point for almost 75% of the total period. Most 15 minute L_{Amax} data were between 45dB(A) and 50dB(A), and only exceeded the 50dB(A) cut-point in three, 15 minute intervals out of the total 562 intervals. It is not within the scope of this report to discuss the question of how many exceedences, if any, of the criteria should be tolerated when considering compliance of the acoustical design.

Comparable single event data is not available from the Sydney study for conventional design housing, however, the study concluded that both the L_{Aeq} and L_{Amax} exceed the OECD criteria at all locations (Carter et al, 1992). The study concluded that the criteria was exceeded "hundreds of times where the windows were open, and many times where windows were closed. Only in one dwelling where bedroom windows were closed and double glazed was the number of 'events' reduced to zero in any one hour during the night".

4.0 DISCUSSION/SUMMARY

This paper has provided preliminary information in describing the effectiveness of a residential development built with acoustic features in comparison to the acoustic amenity provided with dwellings of conventional design.

A quantifiable measure used to compare the improved amenity afforded in acoustically designed dwellings was the average 'mean' outdoor to indoor noise attenuation. It was found that the attenuation in the acoustically designed dwelling was 8dB(A) greater than for conventional design dwellings.

The variability of the outdoor to indoor 'mean' noise reductions over the 24 hour period provides an indication of which noise descriptors are useful to use for night-time internal noise criteria when the internal noise levels are relatively low. Hence for an acoustically designed dwelling the external noise levels should be effectively attenuated such that the internal noise levels reach the 'noise floor' within the units more often. This results in lower noise reductions for noise descriptors (i.e., L_{A90} and the L_{A10} to a lesser extent)which are more sensitive (and thus more variable) to reduced traffic flows. Using these noise descriptors to compare with conventional design dwellings may lead to misleading results.

The noise descriptors based on a shorter time period proved more useful when considering night-time noise reductions due to their minimal variation over all traffic flow conditions. However, it may be the case that designing for a daytime or peak hour L_{A10} or L_{Aeq} noise criterion will also ensure effective control over maximum internal noise levels, or single events, during the night-time period. This is shown by the consistent nature of the internal 'mean' noise levels and outdoor to indoor 'mean' noise reductions for the L_{Amax} and L_{A01} noise descriptors.

The paper adopts an averaging method to reduce noise measurements into 24 hour 'mean' data, and three single average 'mean' data for the 24 hour, the daytime and night-time periods. Due to the averaging within the data reduction process, the process results in more repeatable data which is less sensitive to one-off events. This overcomes the difficultly of single event analysis where a few events exceed the criteria and hence the question of how many exceedances, if any, would be acceptable for compliance purposes. As sleep disturbance has been linked with the number of single events and the noise level of those events (Griefahn, 1992), there would be some disadvantage using 'mean' data as it is not directly related to annoyance. Nonetheless, it is an approach which should be considered more fully in its use to quantify the effectiveness of acoustically designed dwellings and compliance with internal noise criteria.

It is recommended that the current study be expanded to assess more acoustically designed dwellings in Adelaide as well as conventional design homes.

5.0 REFERENCES

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FIGURES

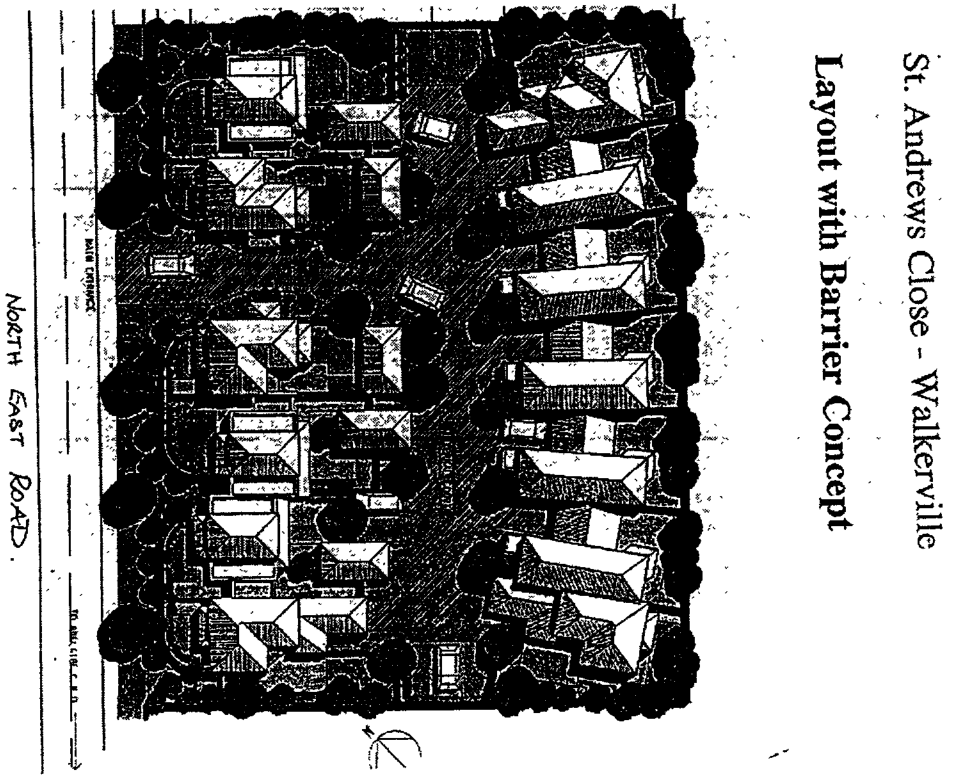

Figure 1

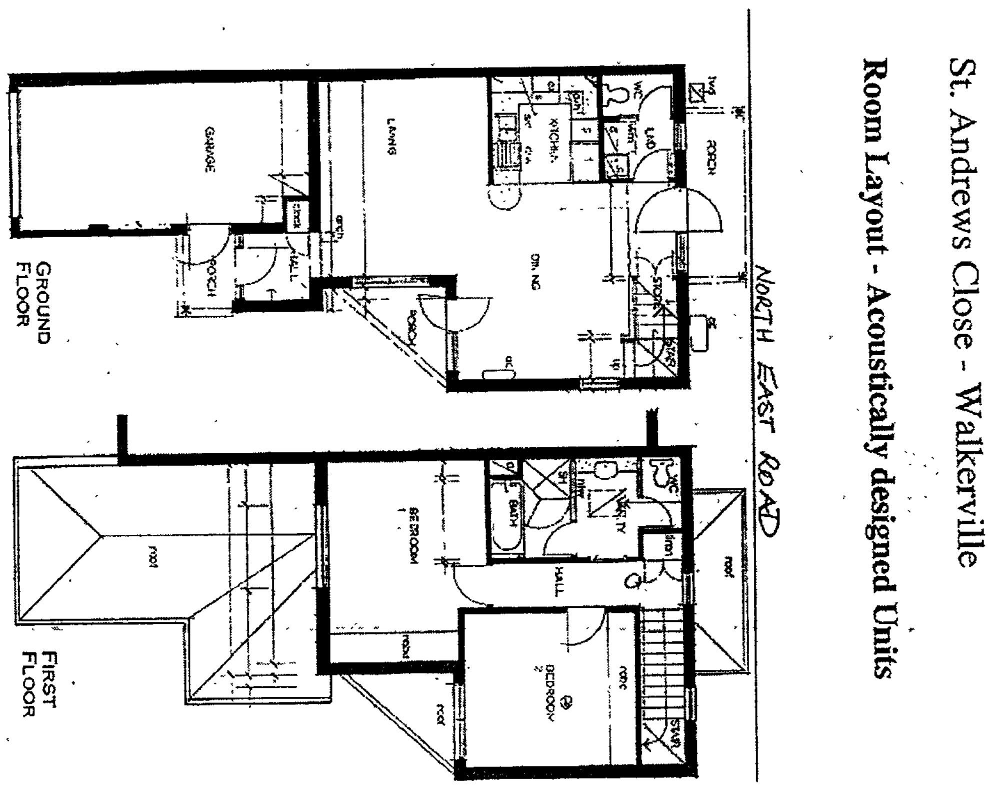

Figure 2

Figure 3 - Mean Outdoor and Indoor LA10 noise levels, acoustically designed dwelling, 15 minute intervals

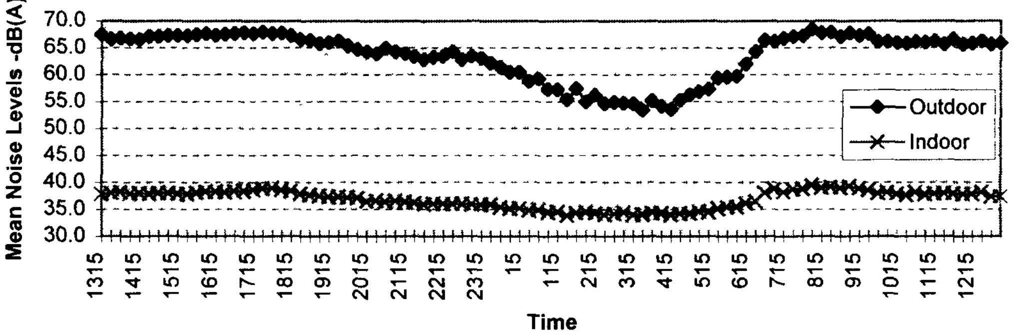

Figure 4 - Mean Outdoor and Indoor LA90 noise levels, acoustically designed dwelling, 15 minute intervals

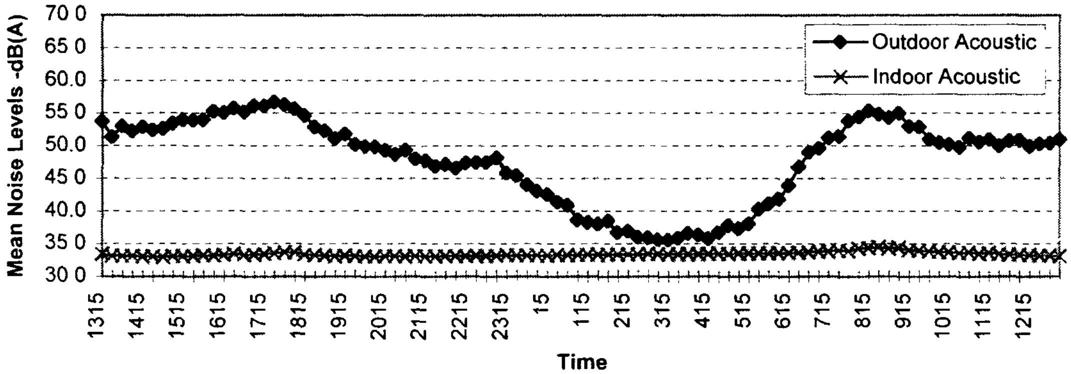

Figure 5 - Mean Outdoor and Indoor LAmax noise levels, acoustically designed dwelling, 15 minute intervals

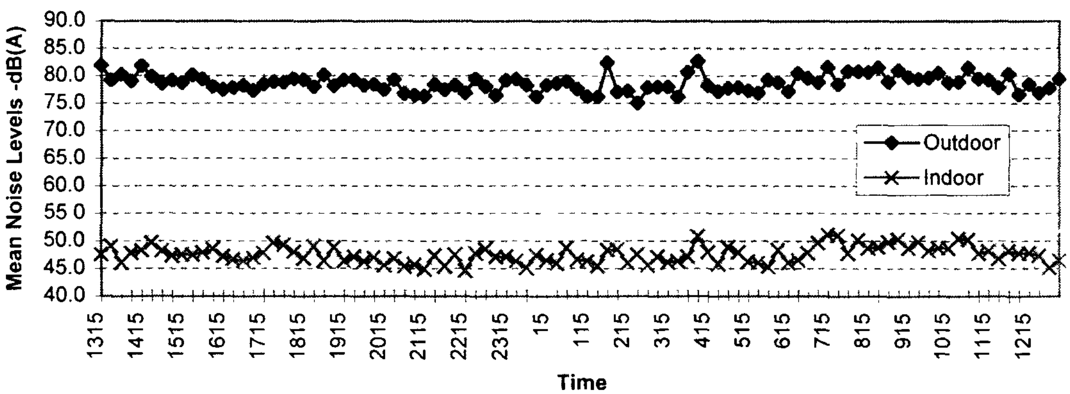

Figure 6 - Mean Outdoor and Indoor LA01 noise levels, acoustically designed dwelling, 15 minute intervals

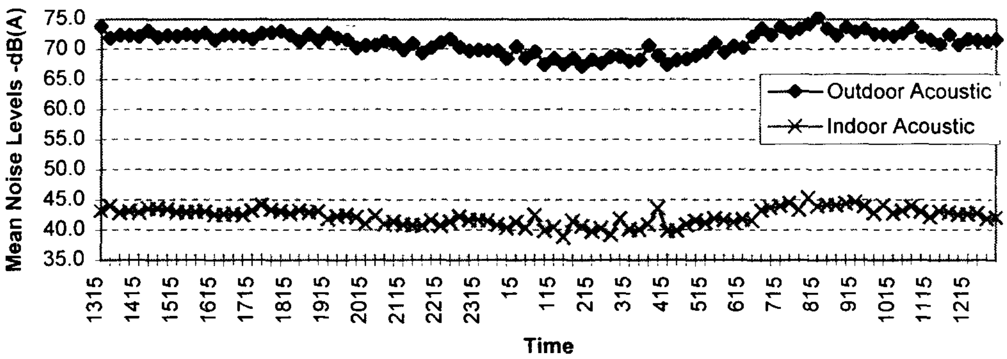

Figure 7 - Mean Outdoor and Indoor LAeq noise levels, acoustically designed dwelling, 15 minute intervals

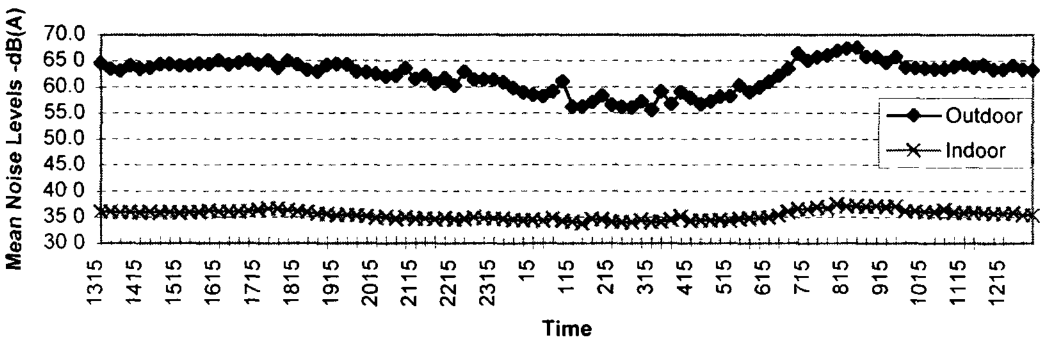

Figure 8 - 24 hour mean outdoor/indoor attenuation for LAeq, LAmax and LA01, acoustically designed dwelling, 15 minute intervals

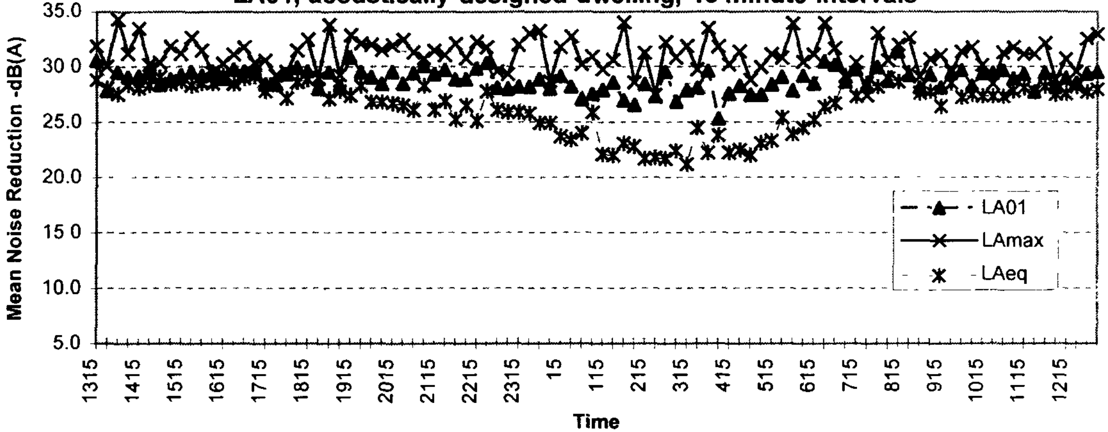

Figure 9 - 24 hour mean outdoor/indoor attenuation for LA10 and LA90, acoustically designed dwelling, 15 minute intervals