JKAU: Eng. Sci., **vol. 11 no. 1,** pp. 193-210 (1419 A.H. / 1999 A.D.)

Critical Evaluation of the Noise Environment with Respect to Academic Activities: A Case Study of some Buildings in the Faculty of Engineering at King Abdulaziz University

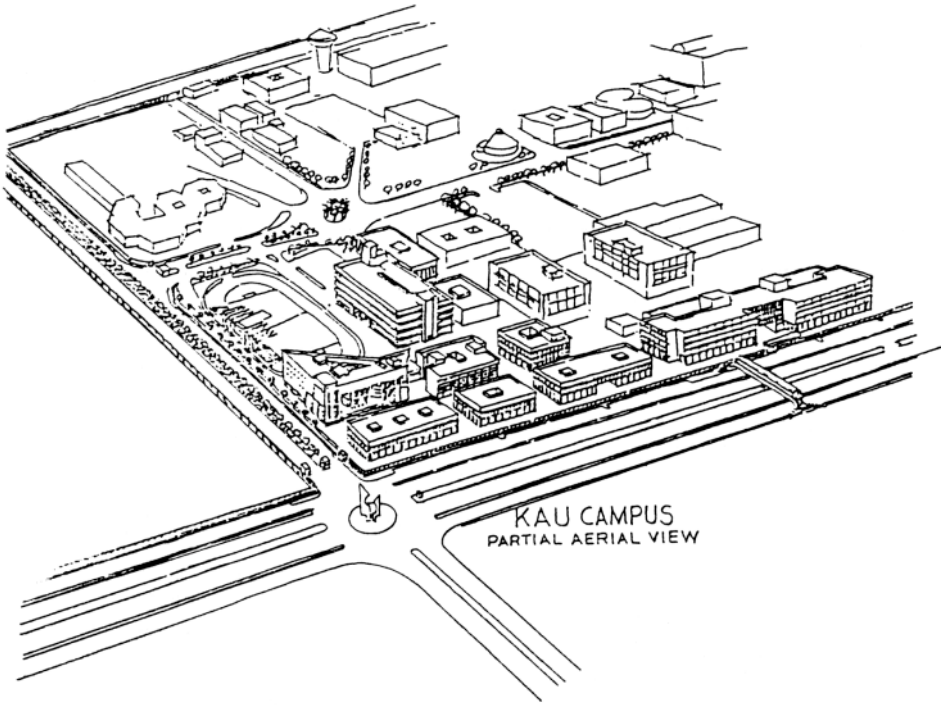
YASSER A. BALILA* and ANIS A. SIDDIQI**
**Department of Architecture, Faculty of Environmental Design, King Abdulaziz University, Jeddah, Saudi Arabia;*
***Department of Architecture, College of Environmental Design, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia*

ABSTRACT. This paper deals with the noise environment in and around some of the academic buildings in the Faculty of Engineering of King Abdulaziz University, Jeddah, Saudi Arabia. It was observed that most academic buildings in the university suffer from unwanted high level of noise emanating from a number of sources. Results from observations have proved the concern real and valid for further attention. Information collected it is being presented here in an attempt to highlight the problem. It has been found that the noise environment of most academic buildings, especially in the Faculty of Engineering, is alarmingly beyond acceptable standards. Noise recordings and observations were made without any regard to the particular source of origin. Also environmental noise in the Faculty Campus arises from ever changing sources which also keep migrating.

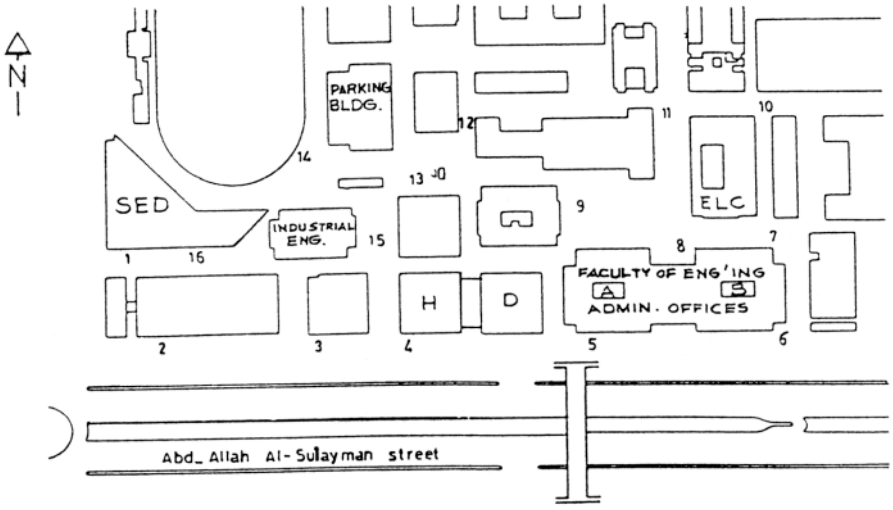
Introduction

The research project was initiated due to undesirably high level of noise prevalent in and around the classrooms particularly at times when a high level of quietness was required e.g. lectures, seminars, discussions, etc. The Faculty of Engineering is flanked by a major road on its southern boundary which is the main link to the Jeddah-Makkah expressway and collects a very large volume of traffic. Incidentally, the heavy traffic on this major road (Abd-Allah Al-Sulayman Street) bottlenecks near a roundabout which adjoins entry to the Faculty of Engineering (Fig. 1).

Internally, there are other sources of noise within the Faculty Campus. Noise is generated by machines powered by roadside diesel generators. Almost perpetual building and demolition work is also a constant source of noise filtering into the academic spaces. These ongoing construction and maintenance works, usually, create traffic diversions thus resulting in traffic congestion and consequently raise the level of environmental noise.



(a)



(b)

FIG. 1. A part view of King Abdulaziz University showing buildings in the Faculty of Engineering, (b) Key map showing locations selected for noise measurement.

Literature Review

The noise levels and the acoustics of the spaces within a building are as important as other building services such as air conditioning, ventilation and lighting. There are several sources of noise which affect the acoustics of a space[1], these are: (a) external noise; road, rail and air traffic, (b) mechanical engineering services; basic plant and supply systems for ventilating, air conditioning and plumbing services, (c) electrical services; lighting and lifts, and (d) people; cross-talk, movement and the noise from machines they used e.g., typewriters.

In our case, although some noises are generated from within the buildings (b,c,d, above), the main source of noise is from the road traffic outside the campus. This research does not concentrate on the relation of noise levels to volume, speed and composition of traffic. It has been attempted to evaluate the overall noise levels outside and inside the buildings and correlate that to the subjective response of students and academic staff.

Also the problem has been attacked from other angles. Social surveys, and field measurements[2,3] indicate a correlation between the noise level averaged over certain hours a day and human dissatisfaction. Besides, noise levels were measured at roundabouts of various geometries and around junctions[4,5].

Traffic noise in developing countries has not been recognized as a major problem and little research work has been carried out[6,7]. More recent work carried out in Jeddah[8,9] indicates that noise from road traffic is very intensive and fairly high sound pressure levels have been recorded in many cases.

On the other hand, Croom[10] surveyed lecture rooms in 16 universities through a questionnaire and site appraisal, and he found out that the acoustics of about one third of 120 lecture rooms were considered unsatisfactory by lecturers, building officers and students.

Researchers would believe that justification for the present work is clear, especially that several buildings of the Engineering Faculty are located not farther than 10 m from busy roads. These noises could affect the education process where interference with the understanding of verbal instruction results. Many processes of teaching depend upon the ability of the teacher to take his students through a sequential train of thought and occasional distractions may have a bad effect on understanding[11]. Also the effect on mental concentration is obvious and learning new subjects may take longer in noisy environment than in quite conditions. So, after evaluation of acoustic environments in and around buildings under consideration, researchers intended to quantify the problem.

Results and Discussion

Sixteen locations were selected around various buildings of the Faculty of Engineering, based upon observations made earlier. These locations, which are shown in Fig. 1b, represent the variety of outdoor spaces in the Faculty Campus. These are also important points of intersection between vehicular and pedestrian traffic. Above all, these locations physically define the boundary of the Faculty.

The general noise level on all these locations 1-16 is almost always very high. This is clear from Fig. 2 where values of LEQ on these locations are plotted for three different times of the day. Readings were taken in the morning (7:30-8:30), at noon (12:00-13:00) and in the afternoon (14:00-15:00). These three periods were considered important due to two factors. First, there is great activity due to movement of men and machines at these times giving rise to high ambient noise environment. Secondly the need for quietness is also high at least on two of the three times selected (morning and afternoon) as serious lecture work takes place at these hours.

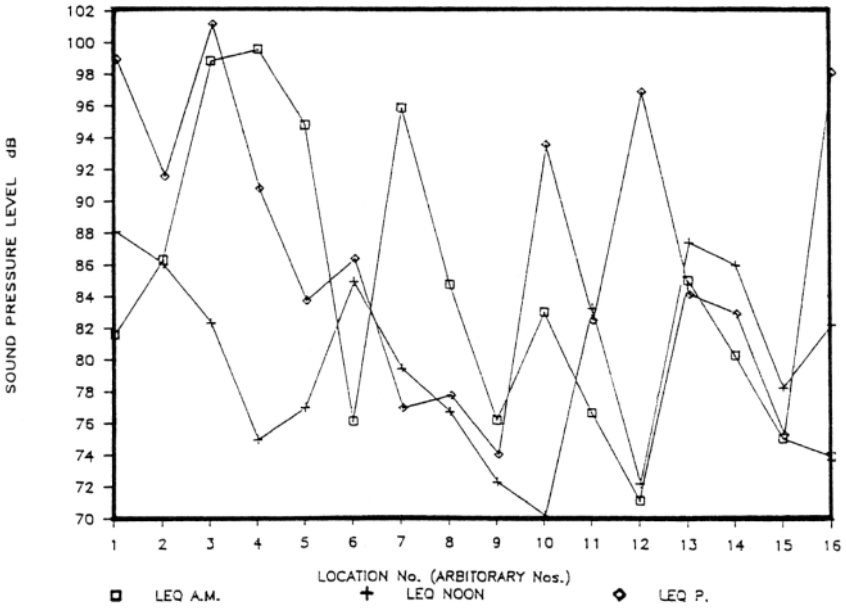


FIG. 2. LEQ measurements plotted for outdoor locations in the Faculty of Engineering (for locations 1-16).

It can be observed from Fig. 1 and 2 that locations 3, 4, 5 and 7 tend to be very noisy during the early morning as well as during the afternoon while noise level drops at these places considerably at noon. One explanation of this behavior is great vehicular movement just across the University boundary wall adjoining the busy Abd-Allah Al-Sulayman Street. This road effectively consists of about twenty lanes. The service lanes of this road are, more or less, used by the students for parking their cars. As most of these students are in a hurry in the morning, there is a high density of vehicular parking around these places. Again, as most students finish their classes towards the afternoon, they are keen to leave and hence the increase in vehicular activity and the resulting high level of ambient noise. On the other hand, the noon time (12:00-13:00) is mostly a time for midday (Dohar) prayer and lunch break and is characterized with sedentary or leisure activity. Traffic noise from the main adjoining road is also due to thinned traffic volume at prayer time. Similarly high prevalent noise on locations 10, 12 and 16 can be attributed to local physical activity. Locations10 and 12, which were (during the period of observation) subjected to high noise levels resulting from construction and demoli-

tion activity, are supposed to be temporary ones, but they have been going on for a very long period of time and now have been accepted as a daily routine on the campus. Re-scheduling of these activities at other than academic hours would greatly enhance the noise environment to the advantage of students and staff. Results regarding noise level on these locations are shown in Figs. 2, 3 and 4.

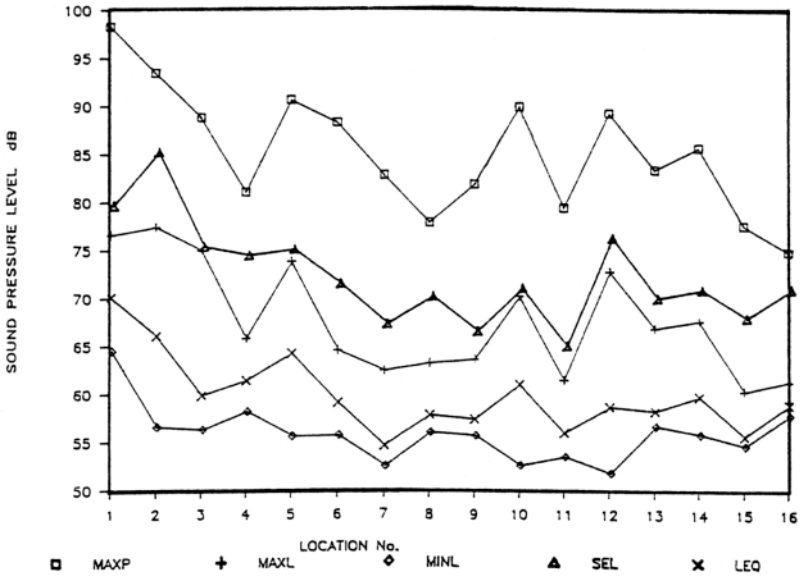


FIG. 3. Noise level outdoor in the Faculty of Engineering as recorded for different times of typical day (a.m., noon, p.m.)

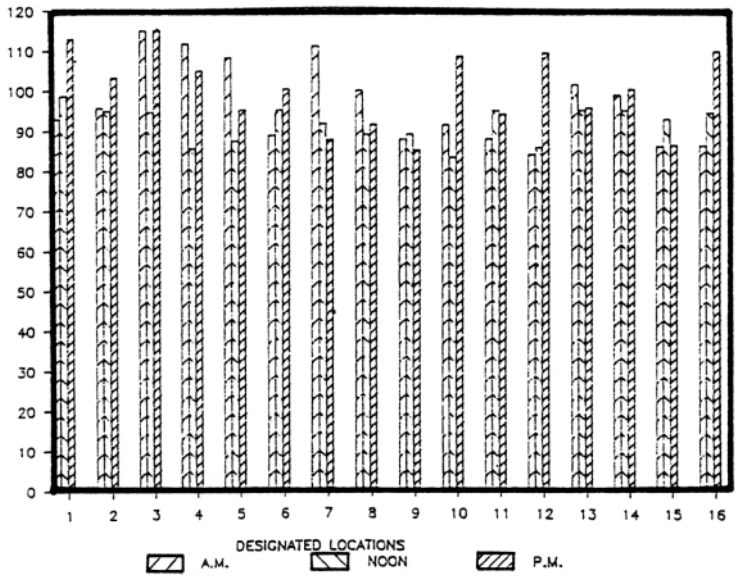


FIG. 4. Bar graph presentation of noise level in the Faculty Premises.

For a closer look at the nature and type of prevalent noise around the faculty buildings a vigorous analysis of the data collected at these locations was performed. One objective of this was to study the sound in detail for not only its magnitude and impact on the user, but also to identify solutions involving detailed acoustic and noise control measures in and around the buildings under study. The collected data for all locations was averaged over the entire period of observation to yield values for each octave band width. It was then analyzed to find out the proportionate contribution of each band width within the entire observed spectrum. The analysis was performed for each of the values i.e. LEQ, MAXL, and MAXP. Results are shown in Fig. 5 and 6.

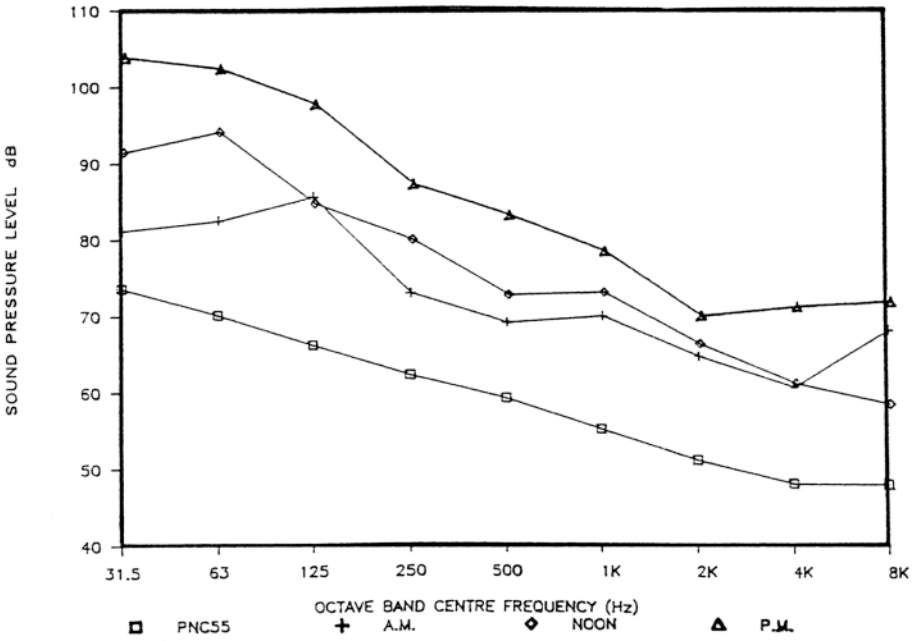


FIG. 5. Outdoor noise level (LEQ) in the Faculty measured at different times of day.

It is clear from Fig. 5 & 6 that the bulk of the noise originates in the lower frequency zone (31.5 Hz - 250 Hz) as compared to the higher frequency range. This suggests that the noise studied is essentially and predominantly of the rumbling nature. If that is the situation, as it is, then it leads to one very important conclusion i.e. the noise must originate from sources which give off low frequencies more than the higher spectrum. It may be safely argued here that this may be due to the traffic that is flowing across the Abd-Allah Al-Sulaiman Street. Vehicular traffic contributes largely in the lower frequency zone in terms of air borne noises whereas it also sends structure borne noise, also at low frequency band, through the road and adjoining surfaces. This low frequency rumbling noise can be predominant in the case of heavy machines such as electric generators, pneumatic drills, and road rollers etc. being operated in the vicinity of the location of observation. This activity (operating heavy machine) is more or less a regular feature of the Faculty landscape and has already been identified as a source of prevalent noise.

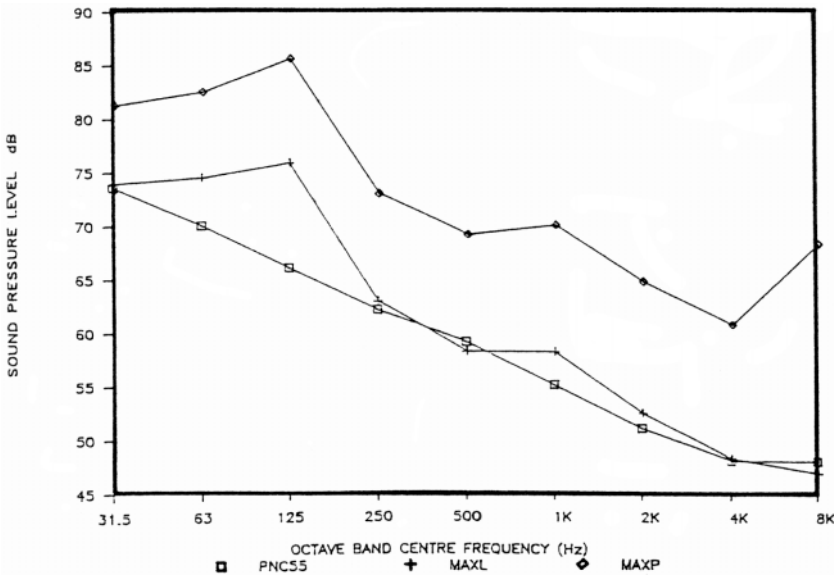


FIG. 6. Outdoor noise level (MAXP, MAXL) in the Faculty of Engineering.

A further implication of this high ambient noise is its filtration into academic spaces like classrooms, design studios and academic staff offices as well as departmental and Faculty libraries. As shall be shown later in this section, this high prevalent noise level is detrimental to academic performance of both staff and students.

To the effect of emphasizing the issue of high ambient noise inside classrooms and offices, a number of observations and recordings were made in different parts of various buildings in the Faculty of Engineering. For the purpose of proximity and ease of data collection, readings were taken in various rooms of the School of Environmental Design (SED) building, while some readings were also taken, for comparison in some rooms of buildings B and D as shown in Fig. 7 and 8.

It was observed by one of the authors that during most morning lectures, classrooms are too cold to be comfortable, particularly for sedentary activity such as sitting and attending lectures. Consequently the students are forced to open most of the openings (windows) to flush out the extremely cool air accumulated during night time. This results in elevating the level of outside pollutants such as dust and ambient street noise inside the classrooms. As the outside traffic noise, due to rush of morning activity, is considerably high, as has been stated previously, the noise situation inside classroom becomes unacceptable. It is not always easy to find a convincing reason to close the windows as the classrooms are very cold indeed. This is particularly true of those classrooms/work rooms which face away from the sun for most of the day e.g. room No. 401 in SED building. A glance at the analyzed data regarding this room (No. 401) shall bring home the point made in this section. It may be noted the noise situation in most classrooms even with all windows closed, is appreciably above the preferred noise criteria PNC 25.

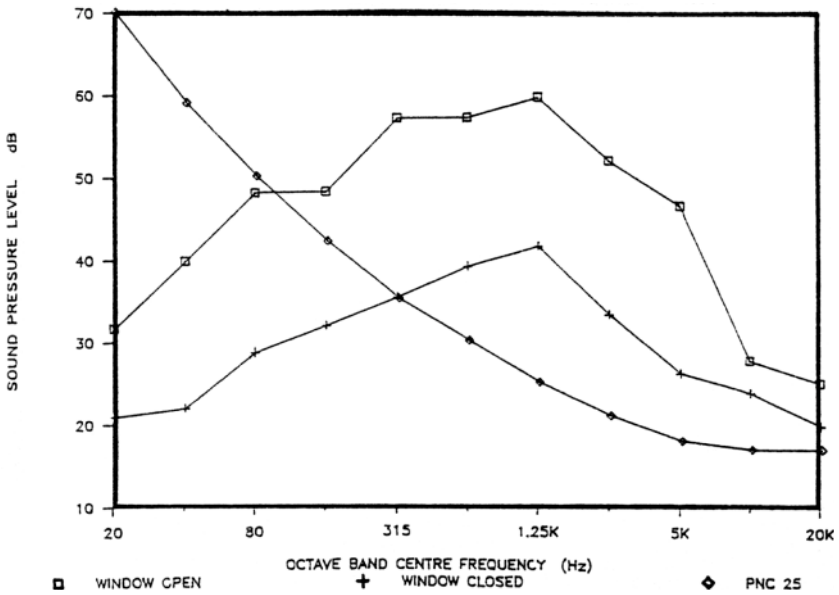


FIG. 7. Noise level as recorded in a classroom of building "B" of the Faculty of Engineering.

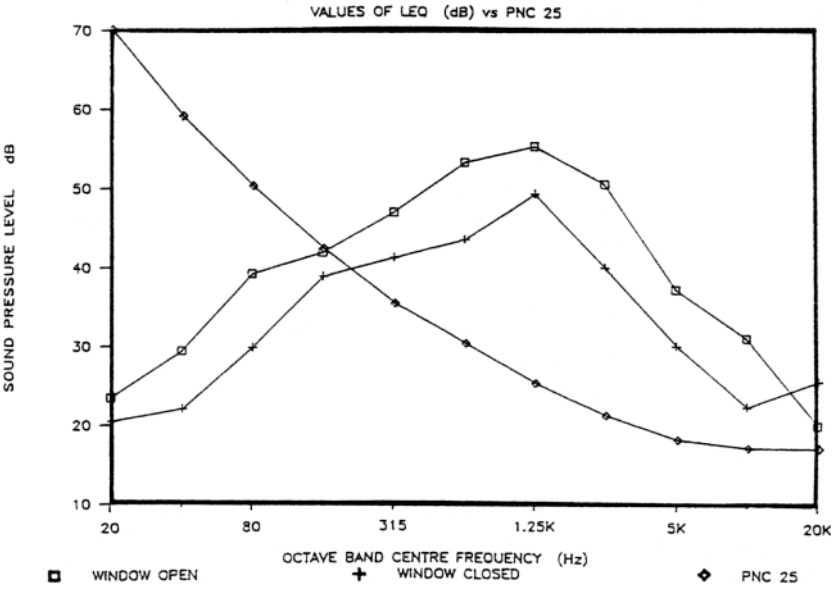


FIG. 8. Noise level as recorded in a classroom of building "D" of the Faculty of Engineering.

Figure 9 shows noise level in room No. 401 at the third floor of SED building. With windows open, the noise conditions inside this room are usually well above the preferred noise criteria PNC-25 [most suitable and recommended for academic activity].

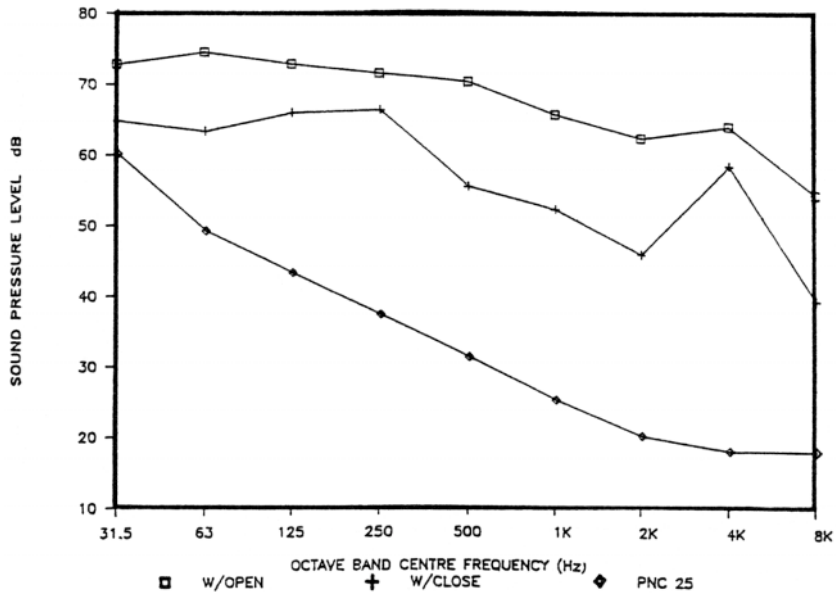


FIG. 9. Comparison of noise level in SED building room 401 with windows open and closed.

It can be observed from Fig. 9 that there is usually an increased noise level of approximately 20-30 dB above the PNC-25 level, depending upon which part of the reading is compared. But under no circumstance the noise level is anywhere close to the acceptable level. Even with all windows closed, which in fact should be a usual situation, and which unfortunately is not, the noise level is far above the acceptable noise criteria. The result of this is interference in speech intelligibility (an area though not covered empirically, but observed) and comprehension of academic communication particularly on the part of the students. This problem is further aggravated when lectures are being delivered by non-Arabic speaking teachers, or those who have a softer voice. Another observation made was the variation in the level of noise in room 401 during different parts of the day. This is clear from Fig. 10 which shows plot of sound pressure level against octave band center frequency for three different times of day (i.e. morning 8:00-9:00, noon 12:00-13:00 and afternoon 14:00-15:00). Although noise level at noon is lower than at other times (for reasons already explained), yet it is well above the PNC-25 curve thus again identifying the noisy nature of the environment.

Similar noise situation is found in almost all the other classrooms in SED and other buildings (Fig. 11-14). However room No. 403 in SED building (this room is generally used for project presentation of senior classes) faces probably the noisiest situation among them all. Partly it is due to its location and partly due to the mechanical (air conditioning system) installed there in and therearound. There are two very large air handling units installed in the planum space above the false ceiling. These air handling units supply air to adjoining rooms and are fitted with very powerful centrifugal fans, the noise level of which is very high.

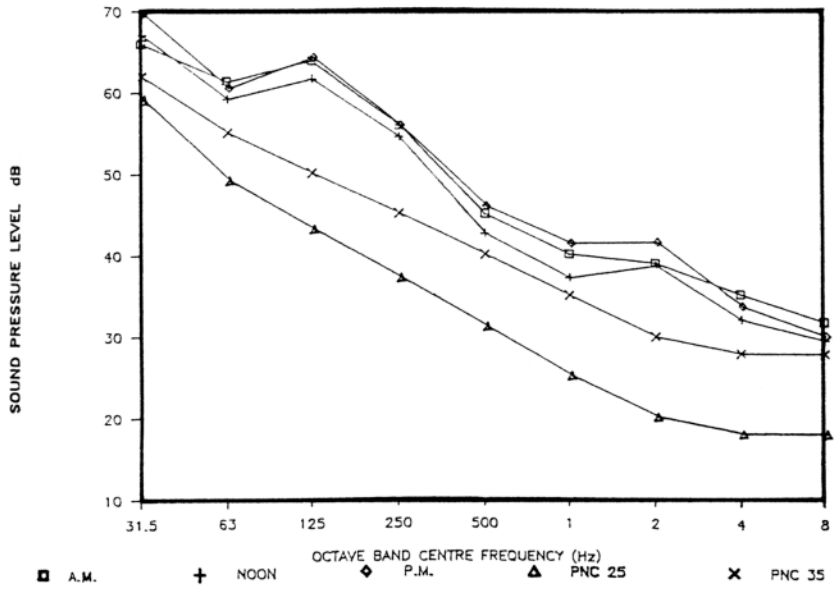


FIG. 10. Noise level recorded in room 401 of SED building for three different times of a day.

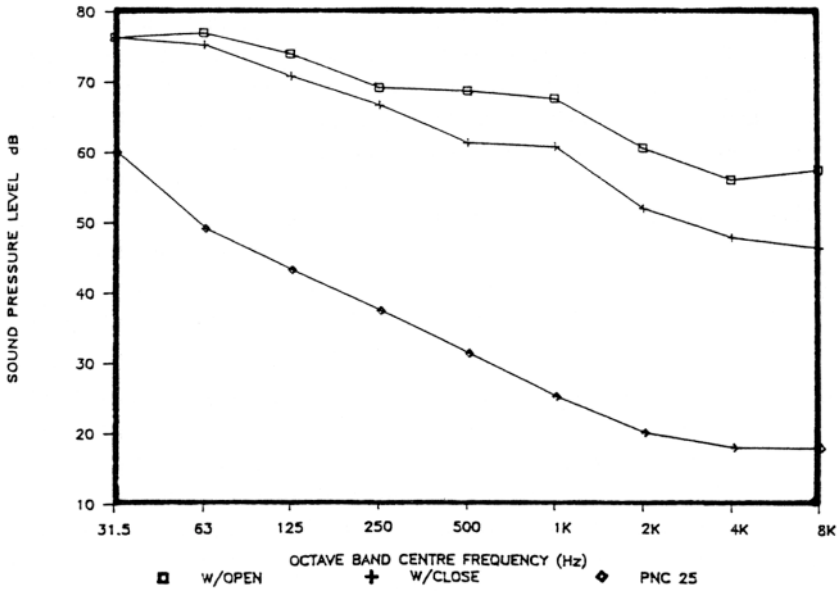


FIG. 11. Noise level in SED building room 402.

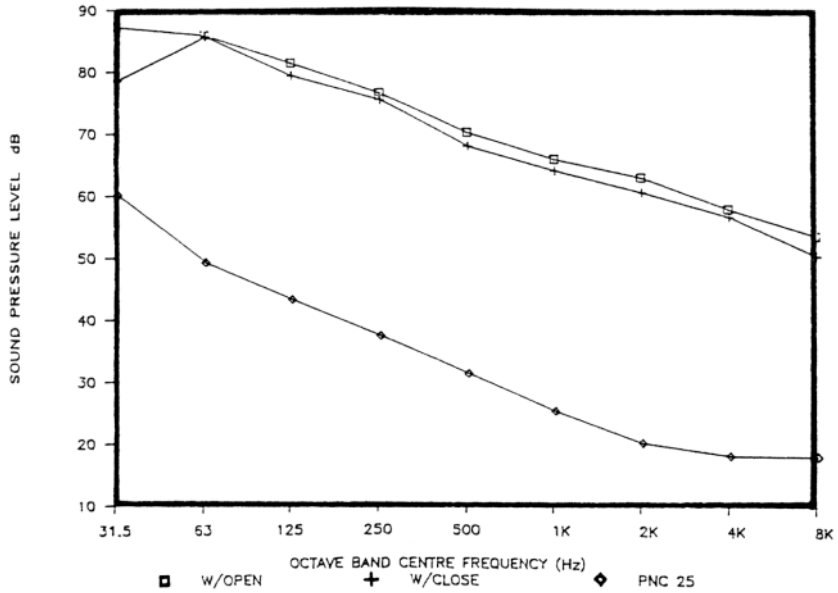


FIG. 12. Noise level in SED building room 403.

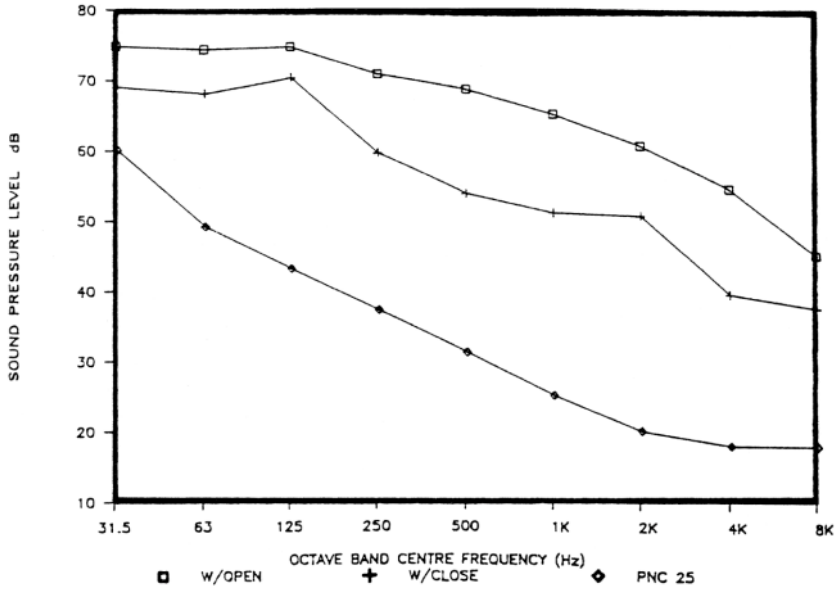


FIG. 13. Noise level in SED building room 408.

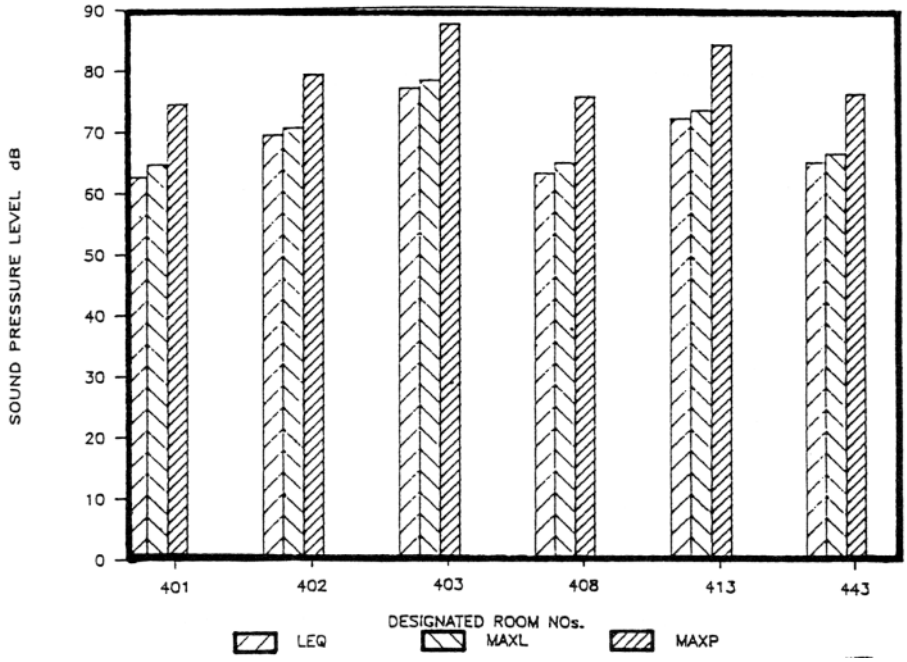


FIG. 14. Comparison of noise level in different rooms of SED building.

All this results in a very high level of ambient noise particularly at low frequencies which produces a rumbling effect. On most days, discussions and presentations in this room are interrupted by requests for repetition and confusion. The overall situation of noise in this room is shown in Fig. 15.

Variation of noise level in different parts (rooms) of SED buildings is further highlighted by Fig. 14 which compares noise level (LEQ, MAXP and MAXL) in six different rooms. One reason was the busy traffic noise from the adjoining road while rooms on the northern side are exposed to low levels of noise as the north side of the SED building faces a service lane and is fourth flanked by the university stadium, which is rather quiet during most part of the day. This locational effect of rooms on ambient noise therein was further investigated and results are presented in Fig. 16. Here sound pressure level at various octave bands are plotted for two rooms (faculty offices); one room (413) situated on the south facade exposed to noise coming from outside main road and the other (443), located on the northern side facing a rather quieter zone. Noise level in the two rooms is compared to preferred noise criteria PNC-25; an essential guideline for academic offices such as those being compared here. It is interesting to note that difference between the two rooms is more marked for higher frequencies (1 k Hz - 8 k Hz) than for lower band.

Speech Interference Criteria and Speech Intelligibility

The persisting high level of noise in classrooms and other academic spaces (faculty rooms etc.) is responsible for much of the academic problems faced by the students.

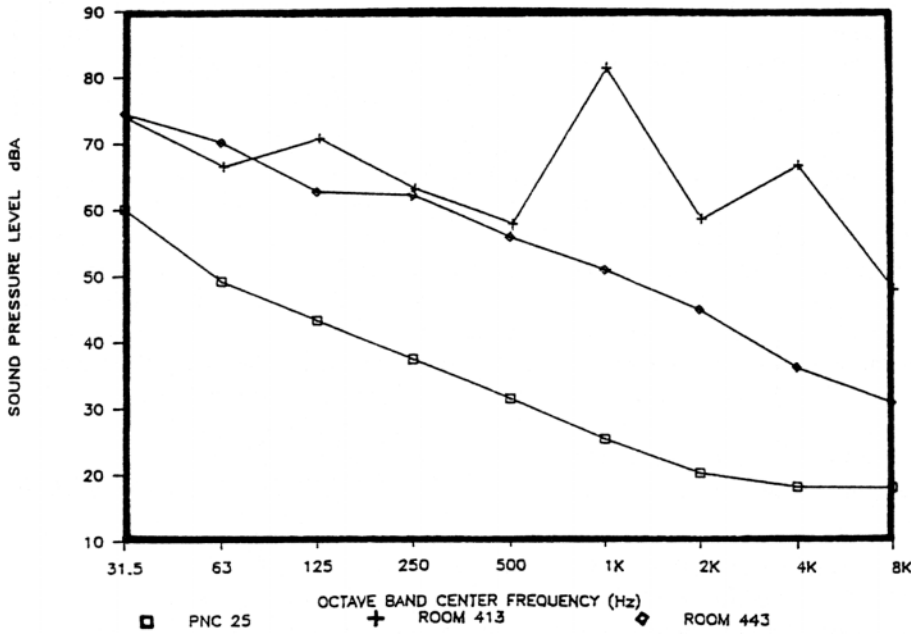


FIG. 15. Noise level comparison between north facing and south facing faculty rooms in SED building.

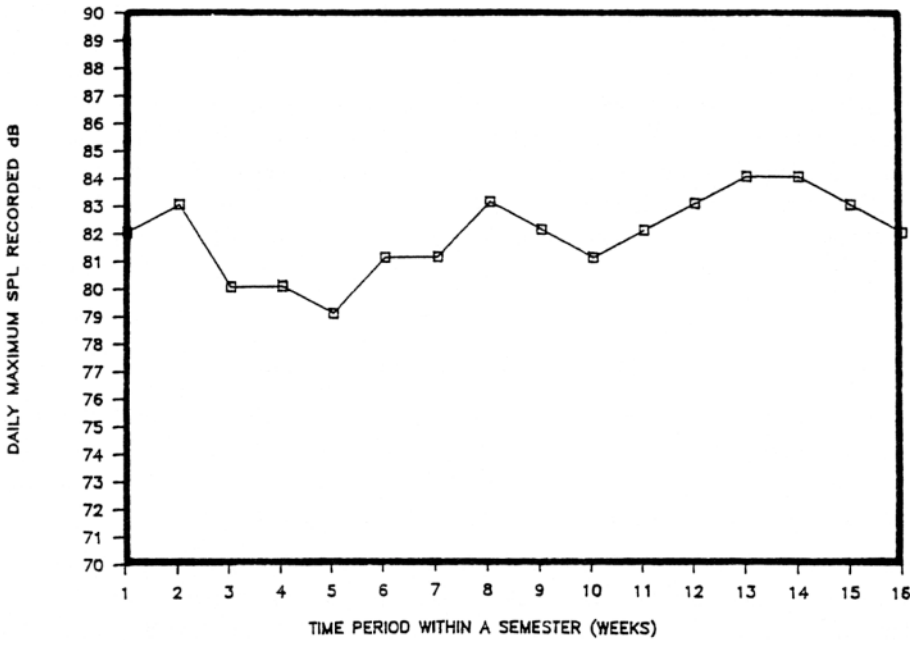


FIG. 16. Noise fluctuation in the Faculty of Engineering during different periods of a semester.

One of such problems is speech intelligibility which, coupled with language problems and other social constraints, can adversely affect the performance of even the best of the students. For speech intelligibility, only an acceptable background noise level can be permitted. This is dependent, among many other things, upon the level of the voice of the speaker (or the output of an amplifier in an auditorium) as well as on speaker to listener distance.

It may be noted here that an average distance between the speaker (teacher) and the listener (student) in most classrooms under observation is in the range of three to four meters. From this point of view a background noise level of 45-50 dB would be permissible assuming a raised voice level. The data collected (Fig. 7-15) however, shows that the prevalent noise level in these classrooms is always well above this criteria. All this can lead to one conclusion i.e. the noise situation in academic spaces, as it exists, must be doing great harm to the students in terms of speech intelligibility and consequently their intellectual comprehension of the education imparted to them. Therefore, the problem, in this case, is essentially that of speech interference, and as the sound level recorded in one classroom (room 401 of SED building) shown in Fig. 10 would prove that as noise is fluctuating frequently, the interruptions can have serious effect on the learning process of the students.

An interesting and useful conclusion, which can be drawn from the detailed study of various rooms in SED building, is that, the design of the building (SED) shows a complete lack of consideration for optimization of physical environment including the noise situation. Air-conditioning systems, though not directly related to noise environment and acoustic control, in most buildings are largely responsible for aggravating an already deteriorated noise situation. This is due to excessive cooling of spaces thus forcing the user to keep the windows open (their is no local control of air temperature). This allows the outside noise in. This amounts to a shear wastage of energy for no useful purposes at all. It further causes great mental discomfort and health hazards, which has been reported by students and staff alike. It may be pointed out that the designer of the building would have produced a better plan by providing classrooms on the safer side e.g. Northern facade while other spaces such as secretarial rooms, stores, and other offices could be conveniently placed on south and western sides of the building. A similar analysis could be successfully extended to other buildings in the Faculty (as has been shown in the case of building “B” and building “D”).

Periodicity of Noise Environment

Data was statistically analyzed to identify periodic fluctuations, if it existed, during a semester. Figure 16 shows result of such an analysis, where values of maximum daily sound pressure level is plotted against weekly periods of the semester. Maximum value for a week was taken from the highest record of that particular week.

It is apparent from Fig. 16 that there is, indeed, a fluctuation in the general noise level in and around the Faculty Campus, clearly showing a pattern of periodicity. Beginning and end of the semester show a high level of noise (always above 82 dB) with a middle high as well. This may be explained in view of the changing life pattern on the Campus.

A semester always starts with a rush of students after a long vacation. Registration and other course issues have to be sorted out as soon as possible before settling down for serious study work. The credit hour system requires the students to commute between different destinations such as their advisor (for academic advice), a course tutor (for course acceptance and approval) and finally to administration (Academic Affairs Offices) for recording the semester loading. Because of shortage of time and due to environmental strains (high temperature, high humidity) most people are obliged to use vehicular means and hence the prevalence of high ambient noise at that particular period.

Similarly high levels in the middle can be attributed to the rush of mid-term activities (mid-term examinations) and a following pre-registration period.

The last quarter of the semester (week 13-16) is a period of fierce activity both by students and staff alike. Students are generally busy in finalizing their studies prior to examinations, which in the Faculty of Engineering requires working on projects, etc. Final examinations are also a great burden on many students and hence it results in increased activity and consequently an elevation in general noise level in the environment. On the other hand, the staff members are busy in finalizing their academic schedule and also preparing for the oncoming summer vacations which requires a lot of administrative patrolling to be performed between various buildings of the university, which are usually far apart from each other. Again for saving time as well to protect one from the harsh environment in those days, there is a great deal of vehicular movement and subsequently increasing the noise pollution around the Campus.

Conclusions

The present study has highlighted the all important issue of high ambient noise in and around the buildings in the Faculty of Engineering. Through statistical analysis it has been shown that the general level of background noise is perpetually very high and certainly does not meet neither the Preferred Noise Criteria nor the standards for Speech Intelligibility. Noise has been identified as mainly originating from the traffic and maintenance machines operating in the vicinity. Based upon the analysis and general comprehension of the noise problem in the Faculty of Engineering, many useful suggestion can be put forward to improve the situation.

1. Most Faculty of Engineering buildings are located very close to main roads. One of these main roads is very wide (about twenty lanes) and acts as a major collector for traffic from the busy Jeddah Makkah Expressway. A very high level of noise comes from the traffic on this road and therefore, it is suggested that this road and traffic thereon should have the following attention:

a. Plantation on Abd-Allah Al-Sulaiman Street is, at the moment, mostly ornamental and does not take care of the noise. There is no noise barrier in the form of plantation between the carriageway adjoining the Faculty and academic buildings. It is, therefore, suggested that plantation (trees not bushes) be grown on this side of the road. It may be mentioned that the design of the university boundary wall does not protect the buildings against noise very well. The slits between the prefabricated panels attenuate the noise into flutter. This can be seen in (Fig. 17).

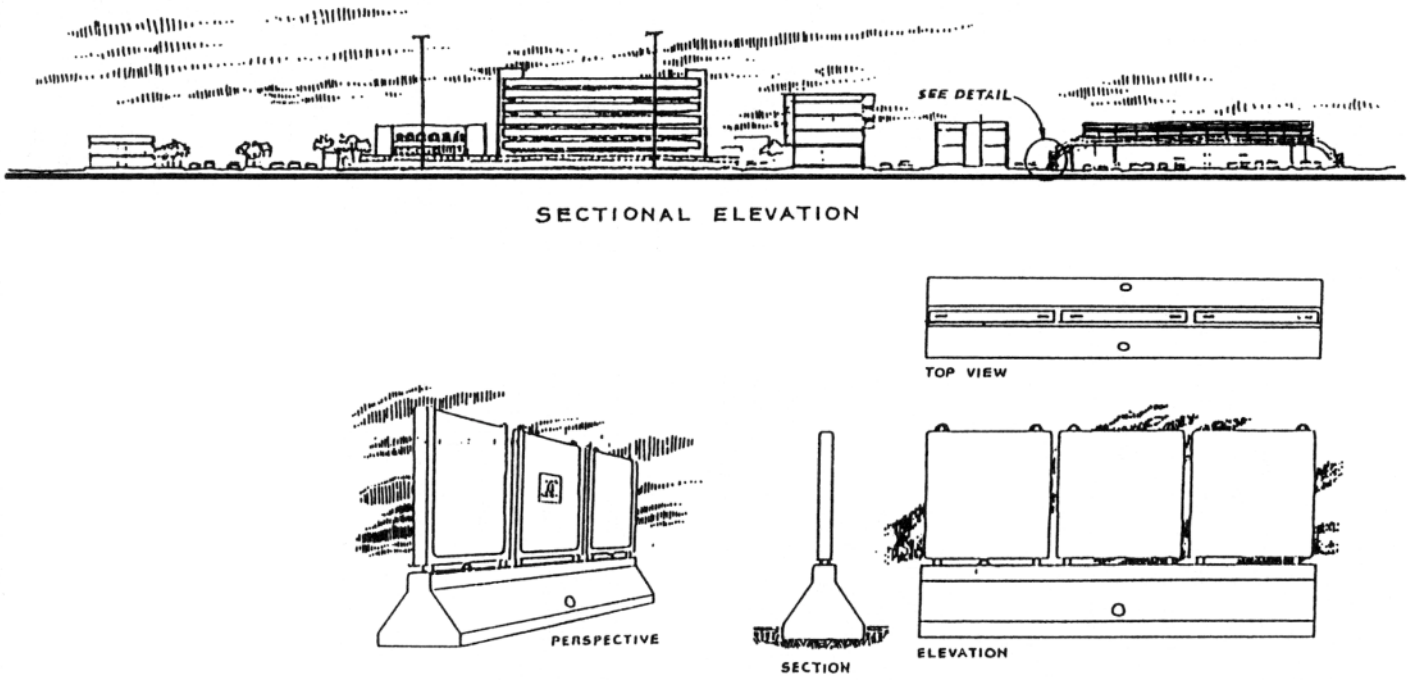


FIG. 17. Sectional elevation through Faculty of Engineering showing physical relation of buildings and adjoining roads. Details of prefabricated pannels of the boundary wall can also be seen.

b It is imperative that this road should be declared a “No Hooting” zone at least for such times of the day that most academic activities take place.

c. The traffic on this road originating from the expressway is usually of a very fast speed and also very high. It is necessary to control the speed on this road with utmost seriousness in the interest of the students.

2. Construction and maintenance activities on the Faculty Campus, which are other big sources of noise, should be better organized. Minimum disturbance due to this activity can be guaranteed if there is a re-adjustment of time table such as work done during afternoons or evening as well as during inactive period of summer vacations.

3.Air-conditioning systems and controls throughout the Faculty buildings have previously been identified as responsible for amplifying the already deteriorated noise environment, and hence require the attention of the concerned authorities to take steps in order to alleviate the situation. This should have an additional benefit of energy saving, as due to this negligence there is substantial amount of energy wastage for no apparent advantage.

4. As the university lies in the flight path of the King Abdulaziz International Airport, there is periodic and intermittent noise contributed from landing planes. A solution to this issue may require re-appraisal of the sound insulation characteristics of building envelopes and in particular the type of glass used in windows. This, however, requires investigations into the problem more closely before any useful suggestions can be made.

References

[1] **Kinsler, L., Frey, A., Coppens, A.** and **Sanders, J.,** *Fundamentals of Acoustics,* John Wiley & Sons, Canada (1982).

[2] **Grifiths, I.** and **Longdon, F.,** *Subjective Response to Road Traffic,* J. Sound Vib., **8:** 16-32 (1968).

[3] **Scholes, W.** and **Sargent, J.,** *Designing against Noise from Road Traffic,* Appl. Acoustics, **4:** 203-234 (1971).

[4] **Lewis, P.** and **James, A.,** *On the Noise Emitted by Single Vehicles at Roundabouts.* J. Sound Vib., **58:** 293-299 (1978).

[5] **Lewis, P.** and **James, A.,** *Noise Levels in the Vicinity of Traffic Roundabouts,* J. Sound Vib., **72:** 51-69 (1980).

[6] **Fuchs, G.,** *Subjective Evaluation of Transport Noise in Latin America,* J. Sound Vib., **43:** (1975).

[7] **Hammad, R.** and **Abdelazeez, M.,** *Measurements and Analysis of the Traffic Noise in Amman, Jordan and Its Effects,* Appl. Acoustics, **21:** 309-320 (1987).

[8]. **El-Sharkawy, A.** and **Aboukhasba, A.,** *Traffic Noise Measurement and Analysis in Jeddah,* Appl. Acoustics, **16:** (1983).

[9] **Alshorbagy, K.,** *Environmental Acoustic and Quality in Jeddah Urban Sites,* Appl. Acoustics, **17:** (1984).

[10] **Croome, D.,** *Noise and the Design of Buildings and Services,* Construction Press, London (1982).

[11] **Moore, J.,** *Design for Good Acoustics and Noise Control,* Macmilan Press, London, p. 50 (1978).

التقييم الدقيق لأثر الضوضاء الصادرة من الوسط المحيط بالنسبة للنشاط الأكاديمي : حالة دراسية لبعض مباني كلية الهندسة بجامعة الملك عبد العزيز

ياسر عبد الرزاق بليلة* و أنيس صديقي**

* *قسم العمارة ، كلية تصاميم البيئة ، جامعة الملك عبد العزيز جدة – المملكة العربية السعودية*

** *قسم العمارة ، كلية تصاميم البيئة ، جامعة الملك فهد للبترول والمعادن الظهران – المملكة العربية السعودية*

المستخلص . يتناول هذا البحث دراسة الضوضاء الصادرة من بعض مباني كلية الهندسة وما حولها بجامعة الملك عبد العزيز بجدة بالمملكة العربية السعودية ، حيث لوحظ أن معظم المباني الأكاديمية في الجامعة تعاني من مستوى عال غير مقبول من الضوضاء تنبعث من مصادر عديدة . وقد أظهرت نتائج الدراسة لمستويات الضوضاء الحاجة الفعلية والحقيقية لمزيد من الاهتمام بهذه الظاهرة . نقدم في هذا البحث المعلومات التي تم الحصول عليها في محاولة لإلقاء المزيد من الضوء على هذه المشكلة . وتبين أن الضوضاء الصادرة من المحيط لمجموعة من المباني الأكاديمية خصوصًا مباني كلية الهندسة تجاوزت كافة المقاييس المقبولة . وقد اعتمد البحث على تسجيل مقاييس الضوضاء ونتائجها بدون اعتبار لمصادرها ، كذلك فإن الضوضاء المحيطة في حرم كلية الهندسة تنبعث عن مصادر متغيرة على الدوام ومتنقلة باستمرار .