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REVIEW ON RESEARCH ON ACOUSTIC PERFORMANCE OF NOISE BARRIERS IN AVIATION

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ABSTRACT

Noise is always an important aspect in the Aviation environment. Various airports are taking measures to reduce, mitigate the noise levels at the airports. Governments and aviation regulatory agencies such as ICAO are also taking initiatives to reduce the same. As per the Balanced approach by ICAO, one of the most important approaches is to mitigate the noise at the airport and an important measure is noise barriers. In this research paper review, possibilities and options worked out for effective noise barrier material has been studied. Along with that, noise measurement and modeling also plays an important role in deciding the location of noise barrier installation. Various materials such coco shell, rice husk, bagasse, and date palm material is studied by researchers to arrive at the conclusion regarding noise barrier in aviation.

KEY WORDS: ICAO, Balanced approach, Modelling, Absorption coefficient, Reflection

INTRODUCTION

Basics of Sound

Sound are vibrations that travel through a medium, such as air, water, solid substances, which is sensed by the human ear. Sound wave propagation depends on the source type, environmental characteristics, and the frequency. When sound is unpleasant, it is perceived as disturbing, it becomes a noise (unwanted sound).

Three characteristics are mainly being considered in case of noise:

- Amplitude
- Frequency
- Duration.

Amplitude is acoustic energy of the sound vibration, and it is generally expressed in terms of sound pressure.

Frequency is defined as no of times air vibrates per second. Depending on its frequency contentsa sound may be perceived annoying. To take this effect into account, environmental noise is usually corrected according to the A-weighting (hence the unit "dB(A)").

Another characteristic of sound is duration or the length of time.

Airport noise due to aircraft is the most contentious environmental issue associated with airport and aircraft operators. Also there are other noise sources at the airport, aircraft noise is major one and is annoys many people. Some of the possible effects related to aircraft noise are: (Hales 2010).

- Annoyance
- Speech interference
- Sleep interference
- Hearing loss
- Health effects (blood pressure, heart zdiseases, etc.)
- Effect on structures
- Effects on historical and archaeological sites.
- Effect on domestic animals and wildlife

Maximum Sound Pressure Level – LA max

This noise event is defined as the highest sound level that occurred. The greater the value, the greater the risk of disturbance or intrusion (Aviation Noise 2013).

Sound Exposure Level – SEL

The energy of the complete noise event were compressed into a constant sound level for one second. This is called SEL and it combines information about the maximum level and the duration of the noise event (Aviation Noise 2013).

Noise Measurement and Modelling

The noise levels are being measured and monitored by airports. The location of the stations are decided based on the various factors such as runway use pattern, flight path, flight altitude, population density of the areas, local legal requirements etc. The noise measurement done on 24x7 basis.

In case of Vilnius international airport the noise monitoring stations are installed after the runway to measure the noise levels (Aviation Noise 2013). The noise monitors are installed in landing and takeoff path of the runways as well as in the community where there is maximum impact on noise or maximum complaints from the specific areas.

Noise Levels During Taxing

Taxiing is the movement of the aircraft on the ground by using own power. Generally, more noise is generated during taxing of the aircraft and it can affect to the community residing near to the taxiways (Asensio, *et al.*, 2010)

At Heathrow airports, various factors like flight track, traffic distribution, runway use, topography etc are considered while deciding the locations of Noise monitoring terminals and for calculating the noise levels (Kluijver and Stoter, 2000; Page, K. *et al.*, 2018)

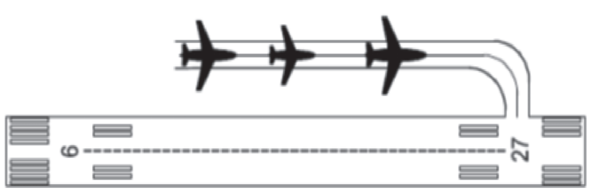

Fig. 1. typical taxiway at airports

Table 1. Heathrow 2011 Lnight area, population and household estimates by contour band (Lee, *et al.*, 2011)

Lnight Contour Band (dBA)	Area (km2)	Population (x1000)	Households (x1000)
50-55	47.8	144.2	60.7
55-60	17.6	51.9	18.3
60-65	5.9	13.7	4.4
65-70	1.8	1.5	0.5
>70	1.5	<0.1	<0.1

Various noise indices are considered like Lday, Lnight, Lden, Lamax, Leq.24 hrs for calculating the noise impact on the community. Typical analysis table is like.

At Herakleion Airport Acoustic characterization of Airport operation inside the study area is done to access the noise impact (Ann Nakashima and Murray Hodgson, 2003)

Fig. 2. Study area of Alikarnassos: (a) Sound Signals and sound marks map, (b) Sound Identity map

By using this methodology, noise assessment around the airport premises is being done and the results are obtained by help of modelling. In some cases benchmarking the noise results with other airports are done. Airports with similar to its operation like passenger capacity, region and location etc are considered for benchmarking.

Calibrating Noise Maps with Measurements

Noise maps can be calibrated by comparing similar measured and calculated noise levels. There are 2 approaches for noise calibration: (Jean Pierre and Nico, 2016)

- **Global correction of noise levels:** Optimise the difference between calculated and measured values (Jean Pierre and Nico, 2016)
- **Local correction of noise levels:** Measurement to be done near to the sources to estimate the source levels by an iterative technique (Jean Pierre and Nico, 2016)

To locally correct noise levels, first create the model for the whole ambient condition in the modelling software. Include sources with roughly estimated emissions. Define receiver positions and import measured levels into them. Other effects like reflections, diffraction, meteorology are considered (Konstantinos Vogiatzis, 2012)

Use of GPS For Noise Mapping

Two types of noise maps uses the measured noise levels as input :

- Short- or long-term measurement
- Maps based on an acoustic model (Lee *et al.*, 2014)

Airports and surrounding communities like high rise buildings, hangers, terminal buildings or any property adjacent to Airport can have impact on the noise contour (Lee, *et al.,* 2014).

Global Positioning System (GPS)

GPS is a satellite navigation system that operated 24x7 and which identifies position and time in auto mode. GPS are available with ~10 m accuracy and altitude accuracy is only 30-50 m. GPS is widely used in the noise mapping and contouring (Douglas Manvell, 2004)

Noise Modelling Methodology

Large scale noise exposure modelling is used in epidemiological research projects as well as for noise mapping and strategic action planning. During large scale nationwide assessment of road, railway, and aircraft noise exposure was conducted in Switzerland for year 2011, for the noise metric LDEN the comparison shows the deviation of 1.6 ± 5 dB(A) (Felix Schlatter, *et al.,* 2017)

Large scaleexposure modelling within the SiRENE study resulted onaverage in good agreement with measurements. The exposure modelling does not exhibit a substantial systematic over- or under estimation, neither for situations with high nor low exposure levels (Stylianos *et al.,* 2012)

At the London airports the NTK system captures data from fixed and mobile noise monitors around the airports. This information always keeps noise model databases up to date (Burton, 2004).

Noise modelling process can be divided into four phases: first phase was to analyse the input data, second phase was to create acoustical model, third phase was to test the created model and fourth phase was to calculate the noise maps and count the inhabitants, dwellings and noise sensitive building in noise zones.

Above contour shows the impact that can occur on communities can be calculated by various methods. The Noise impact can be reduced by taking various noise abatement measures as mentioned in ICAOs balanced approach. Airports and govt. make use of noise assessment data and mitigation measures are to be planned accordingly (Lee, *et al.,* 2013)

Noise Mitigation Measures

International Civil Aviation Organisation's (ICAO) 'Balanced Approach'

The ICAO has developed a comprehensive guideline called 'Balanced Approach to Noise Management'. European Union has converted the same into law through the 'Operating Restrictions Directive' (Gascó, *et al.,* 2017)

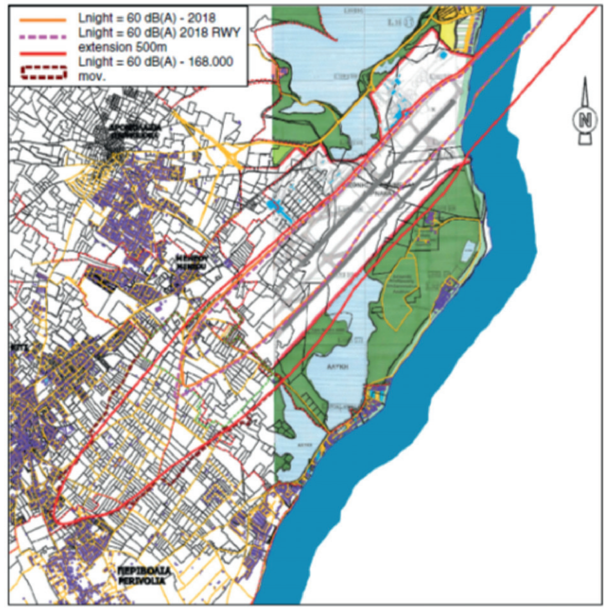

Fig. 3. Noise contour

The balanced talks about identifying the noise problem and then reducing it through implementation of four principal elements, with the goal of addressing the noise issue in minimal cost implication.

The four basic elements are:

- Reduction at source.
- Land-use planning and management.
- Noise abatement operational procedures; and
- Operating restrictions.

This approach entails identifying the various noise problems at an airport and then evaluate the measures available to reduce the same. The goal is to identify the noise problems at the airport and suggest the solution for the same which are least cost implication (Jean Pierre and Nico, 2016)

Effective Noise Abatement Process – Noise Barriers

Noise barriers are solid obstructions built between source of noise and receptors to protect them from noise pollution. Noise barriers are most widely used method of mitigating the noise. They are effective in reducing overall noise levels. Noise barriers used to absorb, transmit and reflect the sound which can be a nuisance to community.

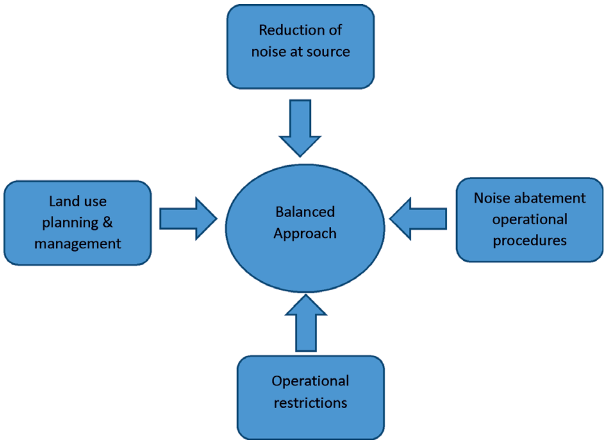

Fig. 4. ICAO's balanced approach (Oleksander Zaporozets, *et al.*, 2015)

A noise barrier must be tall enough and long enough to block the view. Noise barriers provide very little benefit for homes on a hill side overlooking a highway or for buildings which rise above the barrier. When the noise barrier is tall enough to break the line of sight from the source of generation to the receiver, it can reduce the noise levels upto 5 dB. After it breaks the line of sight, addition of barrier height by one meter can result in additional loss of 1.5 dB. (Shahidan, *et al.*, 2016)

Due to the large capital expenditures required to construct or replace a noise barrier, it is important for designers to have information with which to make rational choices between the materials available (Shahidan, *et al.*, 2016)

Wood and metal products were estimated to have 25-year service lives, and earth berms, concrete, and fiberglass were estimated to have 50-year service lives. The results of the life cycle cost analyses indicated that earth berms arethe cheapest alternative while metal barriers with absorptive panels were the most expensive. The life cycle costs of wood, concrete etc were approximately double the cost of earth berms (Amares, *et al.*, 2017)

If a noise barrier is placed midway between the road andthe receiver, the noise reducing effect willbe considerably less than with the below mentioned optimal placing (Amares, *et al.*, 2017)

In the end, these are some consider-ations that needs to be thought about when designing a the noise barrier:

a. Aesthetics
b. Cost
c. Effectiveness
d. Maintenance
e. Safety

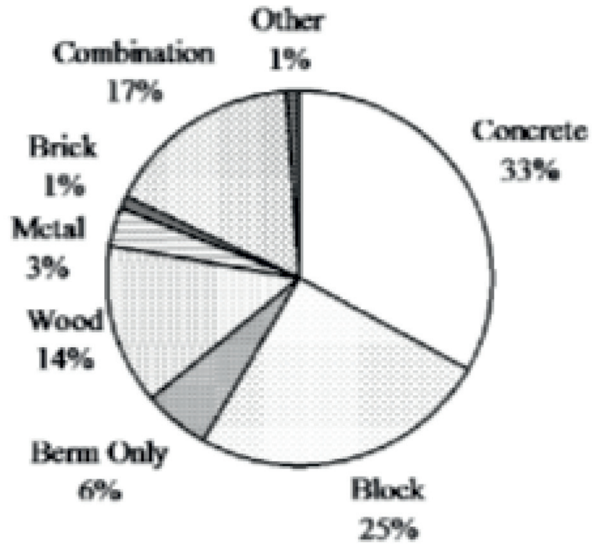

Fig. 5. Percent of total noise barrier by material type (1970 to 1992) (Amares, *et al.*, 2017)

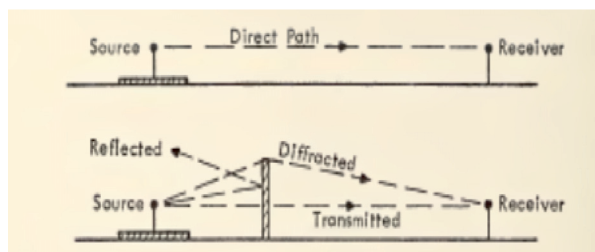

Fig. 6. Optimal placing of Noise barrier

The normal possibilities of achieving various levels of noise reduction in the areas close to the barrier can be outlined as: (Giles Parker, 2006).

- 5 dB is relatively easy to obtain
- 10 dB is obtainable using barriers of considerable size
- 15 dB is difficult to obtain
- 20 dB is practically normally impossible to obtain

Construction materials and barrier placing

The noise-reducing effect of a barrier depends on the following factors:

- The effective height of the barrier.
- The distance between noise source and barrier.
- The distance between barrier and receiver.
- The length of the barrier.
- The thickness of the barrier.
- The materials used for the barrier (Watts and Morgan, 2003).

The traffic noise heard on the side of the barrier facing away from the road consists partly of noise passing over the barrier and partly of noise that has passed directly through it (Giles Parker, 2006).

Noise Barriers- Design Guidelines

Basic strategies for the design of noise screening installations are listed below: (Hans Bendtsen and Danish Road, 2009, Jason Obadiah, 2017; Watts and Morgan, 2003)

- Designed to be merge with the natural surroundings.
- Designed to fit in with the urban environment and nearbybuildings.
- Designed as a landmark, as a conspicuous addition to thelandscape.
- Designed as an independent piece of architecture/work of artand there by become a striking new element in the landscape or urban environment.

Acoustic and Non-Acoustic Performance Of The Barriers

In the acoustic performance Sound absorption Index is being measured by using different tests of airborne sound absorption, reflective sound absorption etc. (Susan *et al.*, 2001)

Noise barriers are generally classified into two basic categories depending on its structure

a) Ground-Mounted and

b) Structure-Mounted.

Ground- Mounted noise barriers systems;

a) Noise berm,

b) Noise wall and

c) Combination of noise berm and noise wall.

Structure-Mounted noise barriers systems;

a) Noise wall on bridges and

b) Noise wall on retaining wall.

Efficiency of noise barrier mainly depends on the height, thickness and material used (Susan *et al.*, 2001)

The following results are derived;

a) The insertion loss higher with increase in the distance of barrier from receiver.

b) The insertion loss higher with higher barrier.

c) The insertion loss higher with increased frequency.

d) The insertion loss reduces with increased surface temperature.

In some areas noise levels were more than the stipulated standards but putting barrier will reduce a good amount of noise in the surrounding areas. (Giles Parker, 2006).

Barrier Profiles

The cross-sectional designs of the different novel barriers investigated, together with appropriate dimensions, are shown below.

For the T-shaped barrier a sound absorptive face on one side and areflective face on the other. The absorptive face was formed from a perforated facing and arockwool material. Due to the same, the side of the panel will be less reflective. The other side of the panel will be un-perforated and was therefore highly reflective (Asif Hassan, *et al.*, 2018)

Characteristics of Noise Absorption Material- Natural Fibers

Acoustic performance of Rice -Husk

The use of natural fibre for sound absorber material has recently investigated. Use of rice-husk wastecan be the potential material for sound absorption material. The cleaned and dried rice husk ismixed with Polyurethane (PU) foamas a binder toobtain composite. Different samples have tested, and it has been found that the best percentage ofrice husk was obtained at 25 percent. The results also demonstrated that the rice husk reinforced composite have abetter sound coefficient compared to other natural materials (Mahzan, *et al.*, 2009)

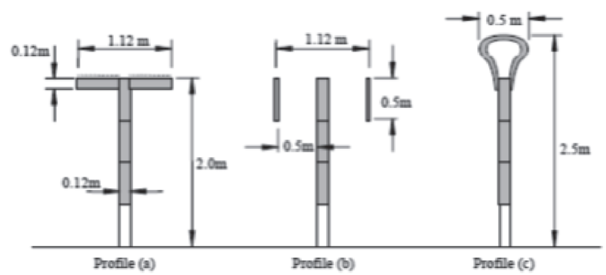

Fig. 7. Test Barrier Profiles: (a) T-shaped barrier; (b) multiple-edge profile; (c) absorptive rounded cap (Bakermans, *et al.*, 2010)

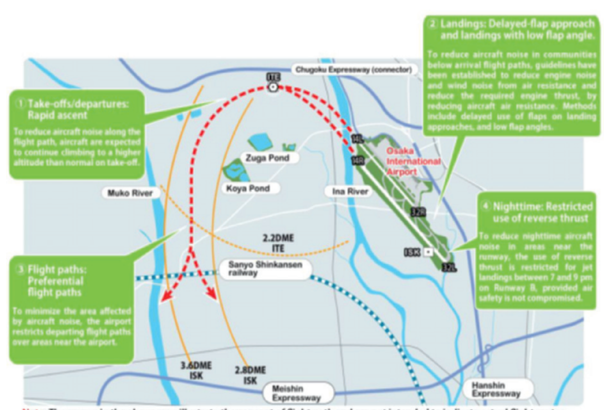

Fig. 8. Noise abatement flight procedures at ITAMI (Yoshiyasu Yukawa, Kenji Matsubara 2019)

Sound Absorption Coefficient (SAC)

Sound absorption coefficient is defined as ratio of absorbed energy to incident energy. Absorption rate is directly proportional to higher the percentages of SAC which meansmost of the sound being absorbed and less is being reflected back (Ebrahim Taban, *et al.,* 2019).

Investigation of the Acoustic Performance of Bagasse

Bagasse is the byproduct of the sugar industry. The acoustic absorption coefficient of bagasse is investigated for three different samples of thicknesses varying from 10 mm-30 mm. Acoustic parameters like Airflow resistivity and Acoustic absorption coefficient is measured to analyse the performance of the bagasse with different noise frequency. The results shows that acoustic absorption coefficient and flow resistivity is directly proportional to thickness of bagasse material (Azma Putra, *et al.*, 2013)

The bagasse material shows the efficiency to absorb the sound with high acoustic absorbing coefficient (0.7 to 0.8) between different frequencies. During further studies, it has been found that the thickness of the fibrous material has a significant impact on acoustic performance and the addition of air gap improves the sound absorption characteristics. (Ulhas Malawade, *et al.,* 2013)

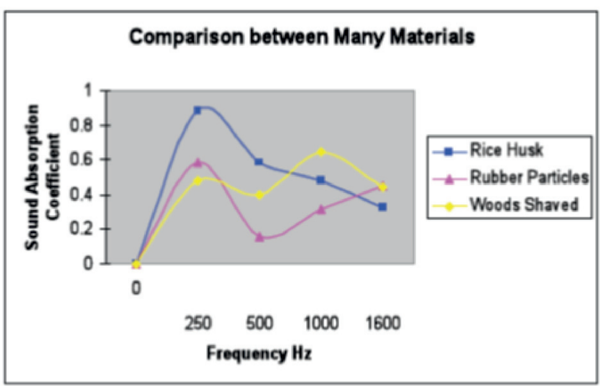

Fig. 9. Comparison on sound absorption coefficient for rice husk with rubber wood (Ebrahim Taban, *et al.*, 2019)

CONCLUSION

Noise abatement in the aviation sector is an important element. Various noise abatement techniques are implemented by various airports in the world. The techniques used by the airports are highly influenced by local regulations and local communities and their needs.

Amongst the various Noise abatement techniques, the Noise barriers are one of the most effective techniques post noise pollutions. The cost effectiveness of the noise barriers used in aviation is a question. Need of an hour is to work upon the noise barriers which will be efficient as well as cost effective.

Also, effectiveness of noise barriers needs to be studied in more depth so that maximum airports can use the noise barriers with less capital investment. There is gap to identify the low-cost technique to mitigate the noise impact on community by developing low-cost noise barrier.

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