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ACOUSTIC ENVIRONMENT IN AN UNDERGROUND STATION

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INTRODUCTION

As cities expand and their population grows, the necessity of developing fast transit systems able to transport the greatest number of people at the lowest cost increases. The underground train system is considered to be one of the most suitable means of transport for travelling inside cities, but in spite of its suitability, the disadvantages caused to the travellers by the high level of noise produced cannot be forgotten. Even if we leave aside the effects of noise on people's health, due to the fact that only drivers will be affected as the travellers stay in the trains for a very short time, we still have to consider the effect of noise on communication. While the degree of annoyance (sleep disturbance) caused by noise varies from person to person, the degree of interference caused by a particular level of noise in communication is a straightforward matter of objective physical masking of desired sounds. If communication is impaired, a part of the sound is lost and special efforts have to be made to overcome the interference. Loss of information caused by noise interference may also be dangerous when it mask auditory warnings or the approach of trains.

ACOUSTIC ENVIRONMENT

The acoustic environment of a subway station is determined by both, the level of noise present there all the time and the acoustic characteristics of the boundary surfaces of the station.

In order to obtain data on the noise at a station, several measurements were taken and recorded at different points in a subway station of the Compañía Metropolitano de Madrid.

The levels of noise

The main sources of noise in a subway station are: a) trains, which produce three clearly different types of noise (arrivals, stop, and departure, b) auxiliary equipment and facilities, such as fans and vent shafts, or heating and air conditioning systems, and c) people.

Noise data were taken when different trains were passing the station running in both directions, and at different times during two hours. Figure 1 shows the graphical record for the level of noise produced by a train when coming into, stopping and leaving the station. These tree situations (arrival, stop and departure) can be clearly distinguished. The results after analyzing this noise in the 1/3 octave bands can be seen in Table 1. Table 1 shows also the results after analyzing the noise in the station produced by auxiliary equipment, people, and any other unidentified source.

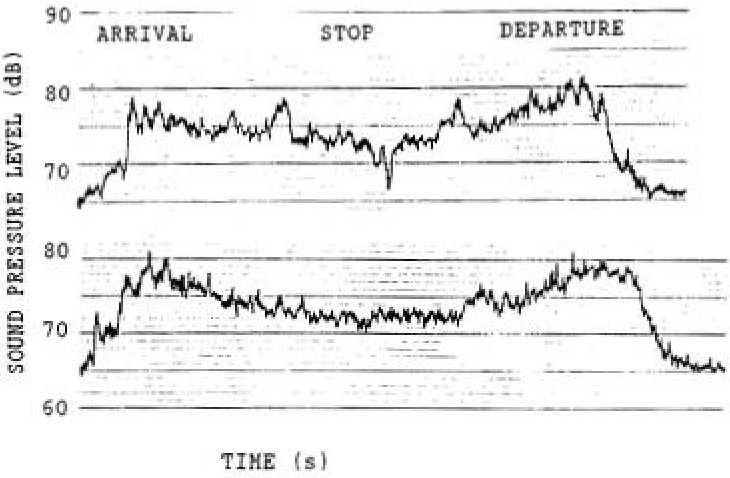

Figure 1
Noise level history of a train recorde in both platform

Table 1
Station noise analysis

FREQUENCY (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000
NOISE OF TRAIN (dB)																				
Arrival	65	61	66	62	67	64	62	66	65	67	62	67	54	52	47	47	45	43	43	38
Stop	64	62	66	62	59	62	61	59	59	61	60	67	55	55	54	52	48	45	41	37
Departure	72	73	71	73	74	69	69	70	71	67	69	76	62	60	57	54	51	49	51	48
NOISE OF AUXILIARY EQUIPMENT AND UNIDENTIFIED SOURCES (dB)	51	48	57	59	42	45	41	41	42	41	39	37	35	31	30	29	29	30	30	30
PEOPLE (dB)	54	52	58	63	50	54	51	52	54	55	46	49	45	39	40	38	40	36	36	34

Acoustic treatment

Acoustic treatment is an important aspect in the design of subway stations. Without this treatment, they tend to be highly reverberant, resulting in excessive noise caused by trains and patron activity, as well as poor speech intelligibility. Reverberation time was measured in order to know the acoustical characteristics of the station. Reverberation time was measured for two positions of de sound source and seven positions of the microphone. Figure 2 and Table 2 show the results of these measurements. The maximum reverberation times measured were 4.73 seconds at 125 Hz, and 4.25 s at 160 Hz.

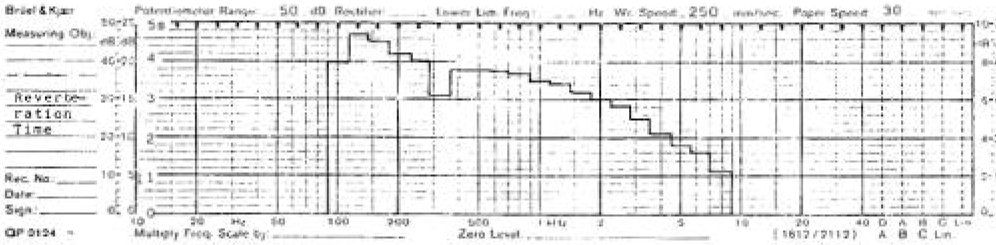

Figure 2
Reverberation time versus frequency in the station

Table 2
Reverberation time measured in the station

FREQUENCY (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000
REVERBERATION TIME (s)	3.97	4.73	4.52	4.20	4.05	3.11	3.78	3.78	3.75	3.63	3.51	3.43	3.19	2.98	2.81	2.46	2.15	1.79	1.59	1.14

The records for the decay of sound at low frequencies show numerous fluctuations in the decay curves caused by the presence of discrete "eigen-modes" in these frequency bands. These "eigen-modes", owing to the size of the station, will form mainly in the corridors leading to the platform. Figure 3 shows the recording of the noise decay curve produced when the source is at a frequency band of 315 Hz, where the variations in the decay slope of the signal can be seen very clearly, denoting the presence of coupling between systems or modes of different energy.

Referring to the mode in which the sound energy emitted in the station is going to be distributed, we have to take into account the capacity of absorption of boundary surfaces as well as their geometrical structure. Two clearly distinguishable structures can be seen both in the platform and in the corridors: the side walls and the ceiling. They are made from concrete or covered with mosaic, both being very reflective materials. The side walls are parallel and thus multiple echoes can be produced. The ceiling is a concave surface, therefore, in order to analyze the direction in which the sound can be distributed, it is possible to use the simple laws for rays reflected at concave mirrors. From figure 4, it can be deduced that the conic section to which it is more similar is that of a hyperbola, since its radius of curvature is larger than twice the distance between the source of noise (train) and the apex. The hyperbolic reflector is a good distributor of sound rays, therefore the sound that can be perceived in a platform will be almost independent from the railway the train uses. Figure 1 allows us to compare the noise produced by the same train measured in two different platforms.

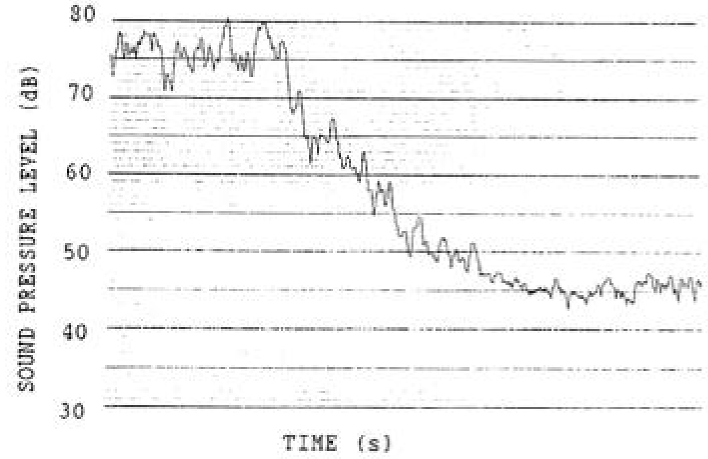

Figure 3
Decay curve recorded using 315 third-octave band of white noise

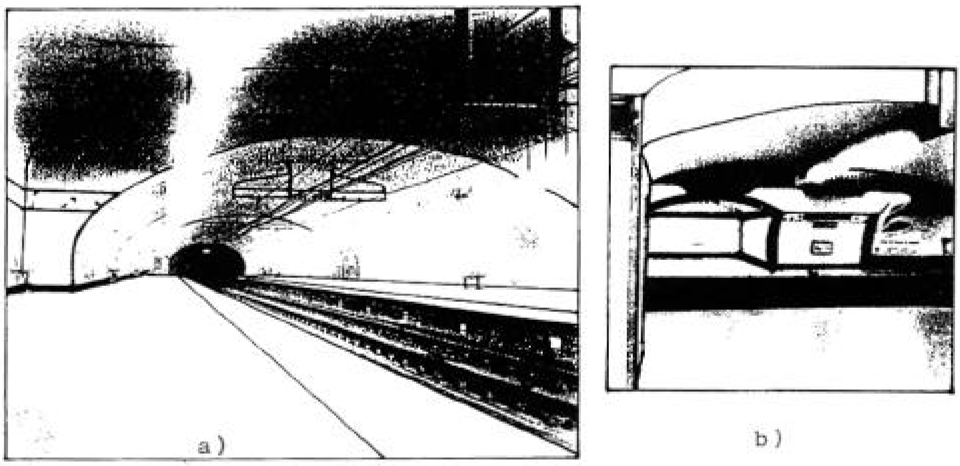

Figure 4
a) Interior view of the statation, b) station view from a corridor

Articulation Index

The Articulation Index was computed from acoustical measurement for the speech spectrum. The values obtained were lower than 0.2.

CONCLUSIONS

Form the results obtained, it can be seen that the absorption capacity is small, since reverberation time is high, thus causing a high reflected sound energy and a low articulation index. The shape of the ceiling is the suitable one as it does not produce energy concentration. The method to use for the acoustic treatment of this station consist in incorporating sound absorption to the ceiling , the projecting under the platform and the sofitos. The values of reverberation time reqiured to obtain an ideal environment must be lower than 2 seconds.