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Absorption of blast sound close to the source

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Abstract

The firing of weapons or demolitions for training purposes normally takes place at dedicated sites. Commonly used, pre-defined training scenarios result in repetitive blast emissions. In many cases, these emissions are dominated by reflections of the blast sound from surfaces close to the weapon or from obstacles that are present at the site during firing. The ground is one of these reflecting surfaces. As a consequence, sound at receiving sites can be dominated by the reflected sound at the source. Therefore, noise abatement measures applied to reflecting surfaces close to the muzzle of a gun or close to a demolition can very effectively reduce the sound at receiver sites.

Close to a blast source, the acoustical levels are very high and the rules of linear acoustics do not necessarily apply for absorption phenomena. In order to develop noise abatement measures close to a blast source, tests were conducted using small demolitions (50 g) and muzzle blasts of a pistol shooting blanks. This paper reports on tests that investigated the use of mineral and steel wool for blast sound absorption. One major result is that the benefits of absorbing materials near to the source are limited by the significant reflections of the blast at the surface of the absorbing material. To reduce this effect, a pile of layered absorbers was tested with the density gradually increasing from layer to layer.

Introduction

Sound abatement measures close to the source are normally preferable to those measures along the propagation path or close to the receiver sites. For large military guns in the field such measures are normally impossible because the missions for training purposes must meet military requirements and cannot interfere with the goals of training. However, at dedicated firing positions pre-defined training scenarios result in repetitive blast emissions. At such positions is a chance to apply sound abatement measures.

One possible measure is a muffler. This rather effective device /1/ is expensive and needs automatic systems to control the position of the muffler in front of the barrel during normal operation. Therefore this solution is only applicable at few firing positions where it is more expensive to stop the use of this position at all. The authors know only two facilities where such a device is used today.

A second option may be putting absorbers and walls behind the weapon in order to mitigate the sound radiation to the rear of the gun where most of the protecting sites are located. Such a measure should be supported by an additional option to reduce the ground reflection from beneath the muzzle.

The layout of absorbers close to the muzzle blast of a large gun must consider high pressures and high temperatures. Therefore, tests were necessary to investigate the behavior of absorbing materials close to explosions.

The test plan

The basic idea of the test plan was to compare the signals of a blast that propagates without any interaction to the signals of the sound that propagates through the absorber. Both paths have the same geometry so that other propagation effects like absorption in air and, in particular, unknown non-linear effects can be assumed to influence the sounds in the same way. In order to measure the effect of absorbing layers, a kind of ‘tube’ was used. This tube was made of piled rings of concrete to be filled with the absorbing material under test, see fig. 2.

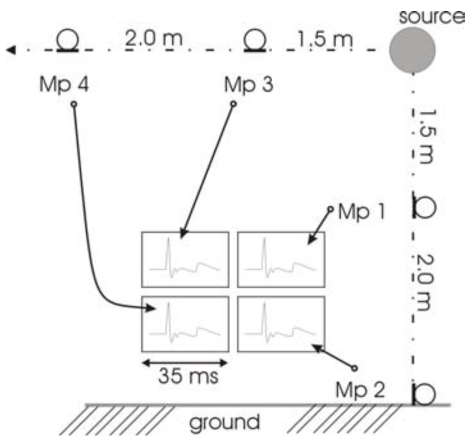

Fig. 1 Basic test plan to measure the absorption and the presentation of pressure time histories used through out this paper

Fig. 1 shows the basic plan including the dimensions. The microphones MP1 to MP3 were piezo-electric microphones, the microphone MP4 was an 1/8” membrane microphone.

This paper reports on the tests using the demolition simulator DM54 as the blast source. The device contains approximately 50 g equivalent TNT and is easily fired by an electric impulse that is also used as trigger for the acoustical measurements.

The charge is packed between soft material but there is also a plastic cap. Normally, this charge provides a spherical blast source. Sometimes however, the plastic cap can produce a sonic boom that is picked up by the microphones.

According to the simple blast model /2/, this charge has a Weber-radius of approximately 1 m. (The Weber-radius estimates the size of that sphere where the expanding gases from the demolition become subsonic.) Therefore, the first microphone was located at 1.5 m distance in order to get ‘acoustical’ pressures.

The following figures always show the time histories of the pressure at all four microphones in the same matrix of charts. The upper left time histories reports the signals at MP3, the upper right shows MP1. The lower left time histories reports the signals at MP4, the lower right shows MP2. The time scaling for all time histories is always the same (35 ms full scale). The time scales are linked to each other by a common trigger. However, the pressure scale is different for each signal. The positive peak pressure of the signal determines the specific maximum scale to allow a direct comparison for the shapes of the signals. For the sake of simplicity, the axes are not labeled; instead, the positive peak pressure in decibels re. 20 µPa is inserted.

The pressure signals were recorded to a digital multi-channel tape. The bandwidth is 0 Hz to 16 kHz. The piezo-microphones and the 1/8” microphone were calibrated using a standard calibrator at 124 dB re. 20 µPa at a frequency of 250 Hz. The influence of limitations of the measuring chain is discussed later.

This paper shows the results of five tests. The first measurement was conducted over the grassy ground of the test site under free field conditions. The second step introduced the concrete tube measured empty in the same geometry. For the next two tests, the tube was filled with different layers of absorbing materials. The last test was a measurement where a simple layer of compressed straw was lying directly at the ground without the tube.

Tests without absorbers

Fig. 3 shows the results of the test without any absorber or obstacle under free field conditions. The readings for the peak level of the two microphones close to the source are different. Nevertheless, MP2, the microphone at the ground, shows the expected pressure doubling comparing the peak level to the respective MP4. All three piezo-microphones indicate the same signal shape; it is a typical blast wave, see /2/.

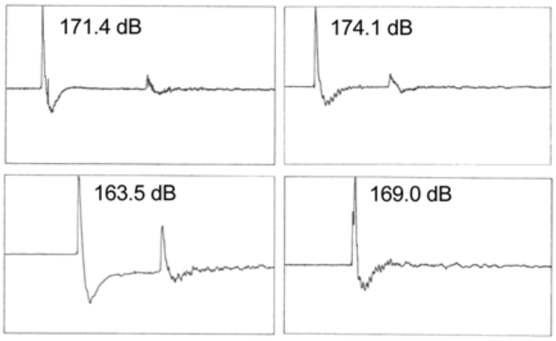

Fig. 2 Pressure time histories for the free field measurement (scaling see fig. 1)

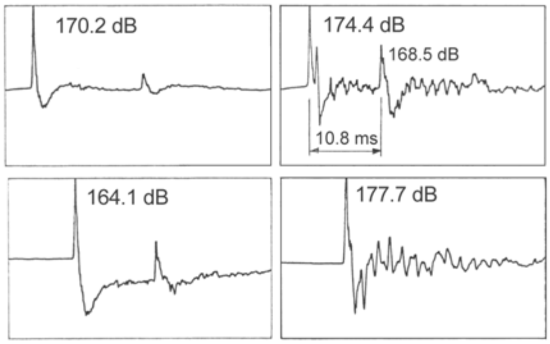

Fig. 3 Pressure time histories in the presence of the empty tube (scaling see fig. 1)

Fig. 4 The test site ready to fire

Demolition simulator DM54 located above the tube, MP3 and MP4 to the left of the source, MP1 and MP2 not visible in the center at the top and bottom of the tube, respectively

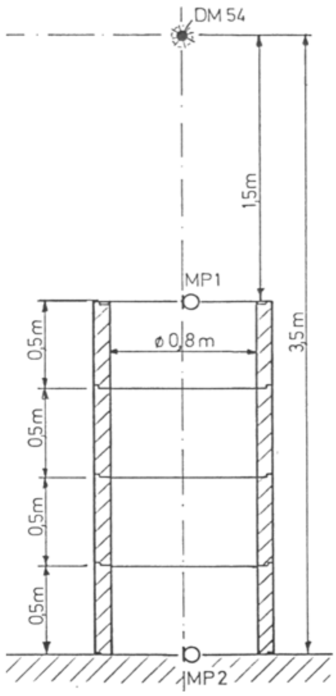

Fig 5 The empty tube including dimensions and measuring positions of MP1 and MP2

The signal of the 1/8” microphone at MP4 is different. Firstly, there is a strong shift to negative pressures after the first positive peak pressure. The reason for this error is a temporal shift generated by the preamplifier of that microphone. This behavior was observed with several devices of the same type. Secondly, the low frequency, negative peak pressure of the blast signal is measured too low even if the shift is taken into account. Calculations show that the phase shift due to the high cut-off frequency for low frequencies of this type of microphone fully explains this result. Considering the shape of time histories of a low frequency blast, the bandwidth at the low frequencies of the whole measuring chain always has such an influence. Here, the signals of MP1, MP2 and MP3 are more reliable with respect to the true shape of the blast signal.

Fig. 5 indicates the dimensions of the concrete tube made of four rings with a height of 0,5 m each. Fig. 4 shows a photograph of the site during these test series. The measured signals at MP1 and MP2, see fig. 3 in comparison to fig. 2, indicate the presence of the empty tube. There is the reflection at the first ring directly behind the first peak. It is rather sharp due to the missing low frequencies that are not reflected by the ring because the size of this reflector is to small compared to the respective wavelengths. The ground reflection at MP1 is delayed by 10.8 ms. Both signals at MP1 and MP2 show multiple reflections that can be explained by reflections from the inner surfaces and joins of the tube rings. The peak level at MP2 is higher due to the missing geometrical spreading for the propagation in the tube towards the ground and backwards.

Test with layered absorbers

Figures 6 to 9 show two tests with absorbing layers piled in the tube. Obviously, in both cases the blast is highly absorbed by the layers. At MP2 the levels are down by more than 20 dB compared to the test without absorbers. Also the signal at MP1 shows no contribution that can be identified as the ground reflection at this resolution of the pressure scale. Instead, the reflection from the surface of the first absorbing layer comes into play.

The first layer is an important feature for the benefit of such an absorber. From a general point of view, this layer must stand the direct heat and gas flow from the demolition. Therefore it is made of steel wool, a material that provides a high heat conduction and can ‘cool’ the gases that penetrate it. From an acoustical point of view, this layer should not reflect the blast wave. This criteria holds, of course, for each following layer of material.

Hence, the goal of the second layout was not to improve the absorption of the blast but to diminish this first reflection. The idea was to start with a layer of steel wool with a rather low fraction of wool with thick fibers and decrease the fiber thickness from layer to layer. Therefore, the major difference between the two steps in fig. 6 and 8 and fig 7 and 9, respectively, is that the first layer in the second case now provides a low density of thick fibers. In other words, the layers in the second case provide a smoother transition of the impedance from air into the absorber. The benefit of this measure is approximately 2 decibels for the first reflection. However, this reflection was still important.

In conclusion, the comparison of this result to the result of the ground reflection of the empty tube yields a benefit of approximately 4 dB for the peak level.

The last test reported here was on a very simple absorber, just a layer of compressed straw lying on gravel ground, fig 10. A thin layer of plastic covered the straw to protect it from rain. Fig. 12 shows the set-up of this measurement. The microphone MP2 measured a sufficient high level reduction of approximately 12 dB comparing the peak level at MP2 to the time history at MP4 and considering pressure doubling due to the ground reflection, see fig. 11. This time, the interesting results are the reflection in the time history of MP1.

The reflection at the straw (the plastic cover, respectively) produces the first peak. The second peak stems from the ground reflection. Though it is not an appropriate resolution in pressure, there is evidence that the reflection at the straw layer provides more high frequencies than the ground reflection; but both peak levels are in the same range.

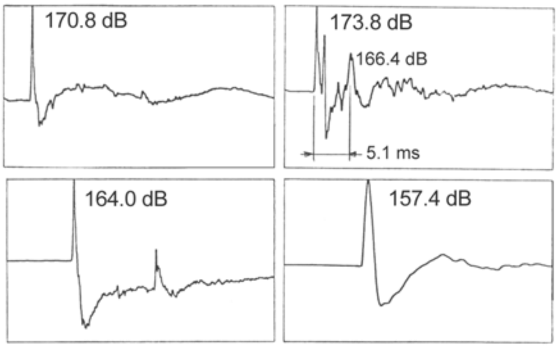

Fig. 6 Pressure time histories for the layered absorber according to fig. 8 (scaling see fig. 1)

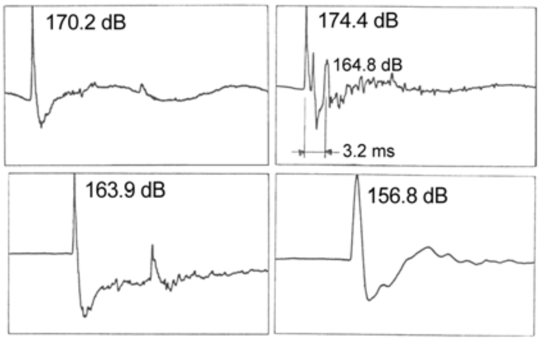

Fig. 7 Pressure time histories for the layered absorber according to fig. 9 (scaling see fig. 1)

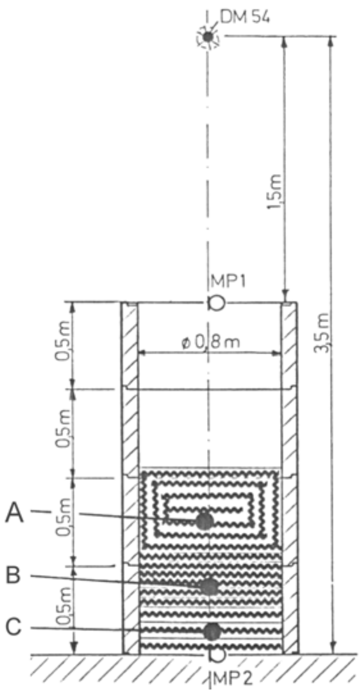

Fig. 8 Tube filled with 3 layers

A. mineral wool ≈ 55 kg/m³
B. mineral wool ≈ 90 kg/m³
C. mineral wool ≈ 140 kg/m³

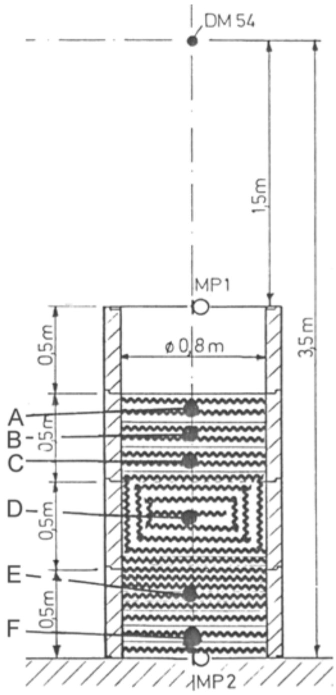

Fig. 9 Tube filled with 6 layers

A. steel wool ≈ 270 kg/m³, fibers Nr. 6, thick
B. steel wool ≈ 270 kg/m³, fibers Nr. 4, medium
C. steel wool ≈ 257 kg/m³, fibers Nr. 2, thin
D. mineral wool ≈ 55 kg/m³
E. mineral wool ≈ 90 kg/m³
F. mineral wool ≈ 140 kg/m³

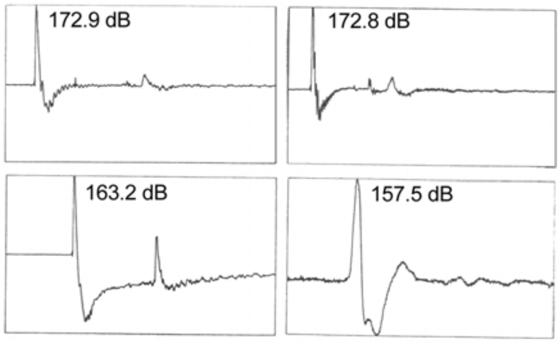

Fig 11 Pressure time histories for the compressed straw, according to fig.12 (scaling see fig. 1)

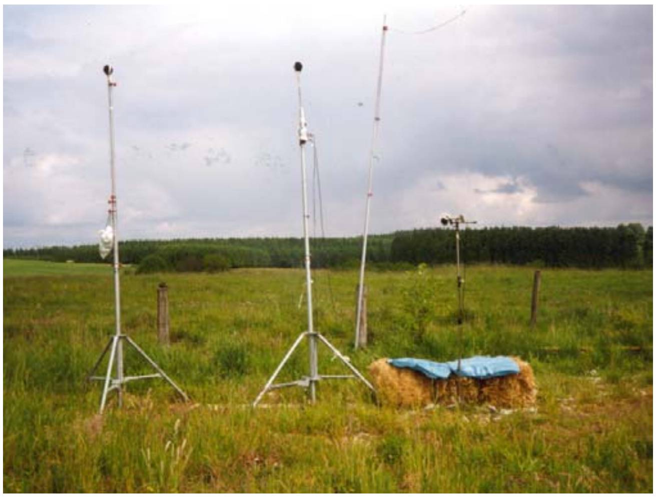

Fig. 10 Test site with straw

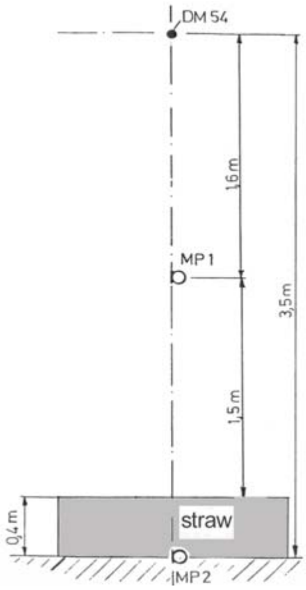

Fig. 12 Straw absorber

The plastic layer is not assumed to influence the measurement. It was just involved in the measurements for practical reasons. To use straw seemed to be a very cheap measure with no problems with respect to the environment.

Summary

The paper presents measurements of blast wave absorption close to the blast source. In general, all tested layered absorbers work sufficiently. The major problem is the first layer that faces the demolition. Reflection from that surface limits the benefit of such absorbers close to a blast source.

Acknowledgements

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References

1. Buchta, E.; Hirsch, K.-W.:”A Muffler For Large Guns”, International Military Noise Conference, April 2001 in Baltimore, MD
2. Hirsch, K.-W.: "Source Data For Shooting Noise", Proceedings of internoise ’98, Christchurch, New Zealand