
# ALTERNATIVE SYSTEMS FOR ROAD SURFACE CPX MEASUREMENTS

Stephen Chiles

NZ Transport Agency, Wellington, New Zealand
Email: stephen.chiles@nzta.govt.nz

## Abstract

Road surface noise can be measured by microphones mounted in close proximity to the tyre/road interface on a moving vehicle. The draft standard ISO/DIS 11819-2 defines the “CPX” measurement method that has been widely adopted by many road authorities and researchers. In New Zealand two CPX measurement systems have recently been developed in general accordance with this standard, but using different approaches: one with a conventional trailer, and the other with instrumentation fitted to a car. There are also differences in the instrumentation and data processing architecture between the systems. This paper compares the designs of the two systems and provides commentary on the requirements of the draft standard.

## 1. Introduction

### 1.1 State highways in New Zealand

Road-traffic is one of the most prevalent sources of environmental noise, and the dominant component is usually generated at the interface between vehicle tyres and the road surface. Accurate information about the acoustic performance of road surfaces is therefore needed to manage community exposure to this environmental noise. This paper describes two recent road surface noise measurement systems in New Zealand that may enhance the management of noise emissions from the state highway network.

The majority of state highways in New Zealand have a chipseal surface, comprising a layer of aggregate embedded in a bitumen binder [1]. Combined with an unbound granular basecourse these chipseal surfaces provide an economic pavement for a network with comparatively low traffic volumes. However, an increasing proportion of state highways now have asphalt mix surfaces, and some of these have been selected specifically to reduce environmental noise. Furthermore, in at least one instance the regulatory approvals for a new state highway have been based on the use of a high performance low-noise road surface being 2 dB quieter than standard porous asphalt.

The NZ Transport Agency has not previously had equipment that could conveniently be used to establish or verify the acoustic performance of state highway road surfaces. Also, using only road side measurements, there has been limited information available on the comparative acoustic performance of road surfaces used locally, such as the different types of chipseal. In common with many international roading authorities, the Transport Agency has therefore explored methods to measure the acoustic performance of road surfaces to allow: comparison of surfaces, development of improved surfaces, verification of new surfaces, determination of acoustic longevity or maintenance requirements of low-noise surfaces, and routine monitoring of the existing network.

The Transport Agency has pursued two routes to establish a road surface noise measurement capability in New Zealand. The first has been to commission research into measurement systems and the longevity of existing porous asphalt surfaces. That contract is currently being undertaken by Opus Research. The second approach has been to support the development of a measurement system by the University of Canterbury. These two projects have illustrated various issues with standard measurement systems.

### 1.2 Measurement techniques

To quantify the effect of road surfaces, sound levels can be measured at the side of a road or in close proximity to the interface between the tyre and the road. There are advantages and disadvantages with both methods, but to address the range of functional requirements set out above, close proximity measurements are the only practical method.

Most close proximity measurements are either based on the draft international standard ISO/DIS 11819-2 [2] or the AASHTO standard TP 76 [3]. The first of these standards defines the close proximity measurement method (CPX) for sound pressure and the second defines the On Board Sound Intensity method (OBSI) for sound intensity. With sound pressure measurements, more basic instrumentation can be used compared to sound intensity, but greater effort is needed to account for reflected sound from the test vehicle and background noise from the test vehicle or other passing vehicles. From simultaneous measurements it has been found that CPX and OBSI results are well correlated with each other, although CPX results are better correlated to measurements at the side of a road [4]. The systems discussed below are both primarily for sound pressure measurements using the CPX method.

### 1.3 ISO/DIS 11819-2

ISO/DIS 11819-2 provides detailed requirements for CPX measurements. The basic method is for two microphones to be located close to the contact patch between a moving test tyre and the road surface. In terms of the test equipment the requirements are generally set as performance standards without limiting how these might be achieved. For example, measurements can be made with the test tyre being on a towed trailer or a vehicle, and for either scenario the test tyre can be on one of the normal running wheels or on an auxiliary wheel. The majority of current CPX systems use a trailer with two running wheels and test tyres being on both wheels.

## 2. Car based CPX system

For the research project undertaken by Opus Research, the time and budget constraints steered the project team towards a car based CPX system with microphones fitted to a standard vehicle. For OBSI measurements it is normal for microphones to be fitted to a standard vehicle, but this appears to be uncommon for CPX measurements.

Conceptually a vehicle based CPX system can meet the requirements of ISO/DIS 11819-2, but practical difficulties were encountered finding an appropriate vehicle to accommodate the standard reference test tyre (SRTT/P1). The SRTT is not a common tyre size in New Zealand so cannot be fitted to most cars. The project team only found one available vehicle type able to be fitted with the SRTT, although this could not also be fitted with the AV4/H1 tyre representative of heavy vehicles.

An advantage of a vehicle based measurement system is the relative simplicity of the equipment required. Figure 1 shows the microphone bracket developed by Opus Research based on designs for OBSI systems. The microphones are mounted vertically which is a minor deviation from ISO/DIS 11819-2. The data acquisition system is located in the back seat of the test vehicle. The system stores all data during measurements for post-processing in MATLAB.

A concern with this vehicle based system is the influence of wind noise, but testing has shown this not to be a significant constraint for the purposes of the research project.

Figure 1. Microphone bracket fitted to the rear wheel of a test vehicle (Opus Research)

## 3. Trailer based CPX system

The University of Canterbury has been investigating CPX measurement systems, initially as a final year undergraduate project, and more recently progressing to construction and commissioning of a trailer, supported by the Transport Agency. The trailer complies with ISO/DIS 11819-2, but as discussed above, this allows for numerous different solutions, necessitating some critical design decisions. A visualisation of the trailer is shown in Figure 2.

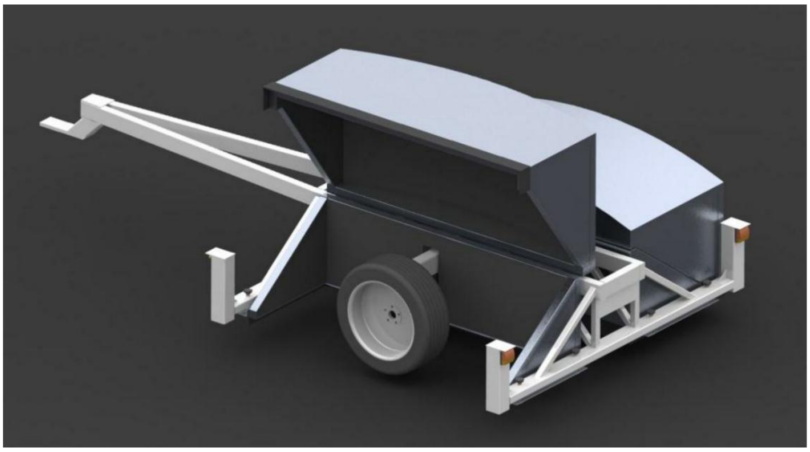

Figure 2. Visualisation of the University of Canterbury CPX trailer (University of Canterbury)

An early design decision was that a simple two wheel trailer should be used, in common with most current CPX systems. This allows for measurements in one or both worn wheel paths of the road and avoids complexities with tracking and loading that might arise with a third wheel. No literature was found that showed a clear advantage to an enclosed or open trailer, and both types are in use. An enclosed trailer was selected to minimise background noise.

An important dimension of the trailer to allow measurements with both wheels is the wheel track width; a parameter not specified in ISO/DIS 11819-2. Current trailers commonly have a wheel track width of around 1.9m [5]. This appears to be based on worn wheel paths in roads being caused by heavy vehicles with a wheel track width around 1.8m. However, medium and light vehicles in New Zealand typically have a wheel track around 1.6m, and while heavy vehicles have a wheel track nominally around 1.8m, the inner set of tyres on an axle may have their centres around 1.5m apart. The choice of wheel track width also dictates the overall width of the CPX trailer. For the University of Canterbury trailer it was decided to use a wheel track width of 1.6m to allow measurements typical of most vehicles, and to limit the overall trailer width.

ISO/DIS 11819-2 recommends that reflecting surfaces are at least 200mm from microphones, which in turn are 200mm from the wheels. For an enclosed trailer, even with a 1.6m wheel track width, this would result in an overall width exceeding the 2.5m legal maximum if microphones were placed outside the wheels. Therefore, similar to many other trailers observed, the microphones have been positioned inside the wheels.

In designing the trailer numerous options were considered for the suspension. ISO/DIS 11819-2 simply recommends the suspension should be similar to that of a car. Initially a swing arm suspension layout was proposed, but this has been simplified using a rubber-torsion based suspension (Duratorque). This has the advantage of reducing reflecting surfaces and leaving better access to microphones. While the damping properties of this type of suspension have not been established, an appropriate type has been selected to result in a ride frequency of 1-1.5Hz, which is typical of a car.

For transporting the trailer, brackets have been included to fit covers over the wheels to minimise water and debris getting on the absorbent linings. The trailer has also been designed so the wheels can be lowered to increase the ground clearance and reduce the risk of damage in transit. This avoids the need for an auxiliary trailer to transport the CPX trailer.

For data acquisition the trailer uses a unit mounted on the trailer with an integrated microprocessor, running LabVIEW software to analyse data in real-time. Advantages of this system are the significantly reduced data storage requirements, and the trailer is independent of the towing vehicle. However, measurements can still be monitored and controlled from the towing vehicle through a wireless connection.

## 3. Commissioning tests

Annex A of ISO/DIS 11819-2 sets out the certification process for a CPX measurement system. Some of these requirements involve significant effort and additional equipment to fulfil. The first requirement is to assess sound reflections from the enclosure. This requires an artificial sound source and an optional design is provided in the standard, although other approaches have also been used [6]. Figure 3 shows the University of Canterbury's implementation of the artificial sound source design provided in ISO/DIS 11819-2.

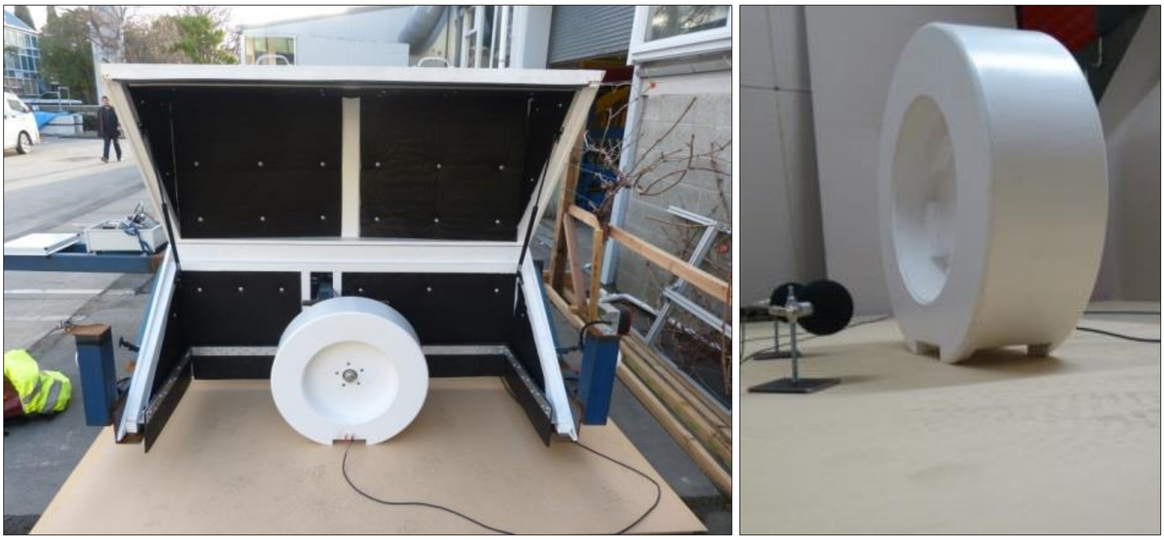

Figure 3. Artificial sound source inside and outside a CPX trailer (University of Canterbury)

The next certification tests are for the background noise from the test vehicle and the towing vehicle (if separate). Three options are provided for the main part of this test being either the:

lifted/removed tyre method, laboratory drum method, or a customised method. The lifted/removed tyre method would be straight-forward for a system with the test tyre on an auxiliary wheel. However, for a trailer with the test tyre on a running wheel, this test requires additional support/wheels for the trailer. In one example an elongated trailer has been used to lift the test tyre [6] and in other instances where this method has been used [7] it is assumed similar external supports have been employed. An appropriate certification test system has not yet been developed for the University of Canterbury's trailer, and this appears to be an area where further guidance could usefully be provided in ISO/DIS 11819-2.

The final certification test is for background noise from other vehicles, which can be conducted by parking the CPX trailer adjacent to a traffic lane and measuring the sound levels of passing vehicles.

## 4. Summary

The requirements for a CPX measurement system in ISO/DIS 11819-2 allow for a wide range of different approaches to be taken. Two different systems have been presented here and some of the practical considerations associated with each of them have been discussed. At the time of writing this paper both measurement systems are due to be measuring the same sections of road. If possible these results will be included in the oral presentation of this paper or will be presented in a subsequent paper. This work should provide an illustration of the reproducibility of the CPX method with more diverse measurement systems than have previously been compared in round robin testing.

## Acknowledgements

The measurement systems discussed in this paper have been developed by the University of Canterbury and Opus Research. The author is grateful to both organisations for sharing details of their measurement systems and data.

## References

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