# Integrated test system for tyre/road noise – *ISO/DIS 11819-2 and AASHTO TP76-12* methods

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## ABSTRACT

A CPX trailer for tyre/road noise measurements was constructed and certified in accordance with ISO/DIS 11819-2. The trailer is a two-wheel trailer (one for test tyre and another for support tyre) with an acoustic enclosure made of sheet metal. To measure the tyre/road noise according to AASHTO TP76-12 method (sound intensity method), a pair of sound intensity probes, constructed using the high precision B&K type 4958 microphones, were also mounted on the trailer. An integrated test system consisting of the acoustic sensing and a position sensing system are presented in this paper.

Keywords: CPX trailer, OBSI method, tyre/pavement noise

## 1. INTRODUCTION

There are two proximity methodologies for the measurement of tyre/road noise – sound pressure method and sound intensity method. Both methods are documented by international standards - ISO/DIS 11819-2 for *close-proximity method* [1] (CPX) measuring sound pressure and AASHTO TP76-12 for *on board sound intensity method* [2] (OBSI).

The major concerns for the CPX test are the background noise contributions on the test results. The background noise includes the noise from the test vehicle system itself (towing vehicle and test vehicle, e.g., a trailer) and the other vehicles passing-by. As usual, an acoustic enclosure around the test tyre (microphones) can be designed to minimize the background noise contributions. The enclosure needs to be specially designed and certified in accordance with ISO/DIS 11819-2 so that the tyre/pavement noise levels measured in the enclosure are comparable with those from the other sources. In other words, the test results shouldn't be influenced by the background noise (unwanted noise) and any reflections except for the test wheel and ground (in an acoustically free field).

## 2. CPX TRAILER

### 2.1 Construction

The Vipac CPX trailer is a two-wheel trailer (one for test tyre and another for support tyre) with an acoustic enclosure made of sheet metal. The enclosure consists of two separate chambers for each wheel and the overall dimensions of the enclosure are 2440 mm x 1700 mm x 1000 mm (L x W x H). To reduce the reflection in the chambers the 75 mm insulation blankets are installed in both the test and support wheel chambers. A photo of the test trailer appears in Figure 1.

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Figure 1 – A photo of Vipac CPX trailer

## 2.2 Certification

The procedures and results for the certifications of the Vipac CPX trailer are detailed in the Vipac technical report 30U-12-0144-TRP-331879-0. The results of the certifications are summarized in the following sections.

### 2.2.1 Sound reflections against enclosure (A.2. ISO/DIS 11819-2)

According to ISO/DIS 11819-2 the influences of the reflection against the enclosure, microphones/holders and objects such as tyre axis and frames shall be determined. The resulting effect shall be reported in every third octave band from 315 to 5000 Hz. In all third octave bands from 315 to 5000 Hz the effect of unwanted reflections shall not be larger than 3 dB.

To generate the noise for the tests an artificial sound source was made to have approximately the same geometry as the test wheel and tyre according to A.2.3., ISO/DIS 11819-2. This sound source replaces the test wheel/tyre in the enclosure to conduct this stationary certification test. The test procedures are detailed in A.2.3., ISO/DIS 11819-2. Table 1 presents the certification results $Cd_f$ for the reflection influence of enclosure.

Table 1 – Device correction value $Cd_f$ (dB)

| | **Third octave band central frequency (Hz)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **315** | **400** | **500** | **630** | **800** | **1000** | **1250** | **1600** | **2000** | **2500** | **3150** | **4000** | **5000** |
| Reflective influence-test 1 (dB) | -1.5 | -0.8 | -0.4 | -0.3 | 1.9 | -0.3 | 2.0 | 1.8 | -0.4 | 2.6 | 0.4 | 1.4 | 0.6 |
| Reflective influence-test 2 (dB) | -1.4 | -0.9 | -0.5 | -0.4 | 1.8 | -0.4 | 1.9 | 1.9 | -0.4 | 2.5 | 0.3 | 1.3 | 0.5 |
| Measurement repeatability (dB) | -0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | -0.1 | -0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Device correction $Cd_f$ (dB) | -1.5 | -0.8 | -0.4 | -0.3 | 1.9 | -0.3 | 2.0 | 1.8 | -0.4 | 2.6 | 0.4 | 1.4 | 0.6 |

The $Cd_f$ values in the table above will be applied on the CPX test results conducted in future.

### 2.2.2 Background noise from test vehicle and towing vehicle (A.3 &A.4 ISO/DIS 11819-2)

In accordance with ISO/DIS 11819-2 the unwanted noise from the entire test vehicle system must be not more than 2.0 dB in the 315 – 400 Hz range and 1.0 dB in the 500 – 5000 Hz range of the third-octave-band spectrum.

Three alternative test methods are specified in ISO/DIS 11819-2 for testing the influence of background noise from test vehicle and towing vehicle on the test results.

- Lifted/removed tyre method
- Laboratory drum method
- Customized method – any other method designed in accordance with good acoustical practice, e.g., determination of the insertion loss of the enclosure

The 'lifted/removed tyre' method was implemented in this project. To do this the noise levels at microphones at standard positions were measured with and without (tyre removed) test tyre contact to the road surface. The differences on each third-octave-band from 315 – 5000 Hz between two measurements were used to judge the certification requirements.

For the tests five runs with and without the test tyre were respectively operated. Table 2 shows the average noise levels for five runs with and without test tyre.

Table 2 – Noise levels averaged at two microphones for 5 runs with and without test tyre

| **At front microphone** | **Third octave band central frequency (Hz)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **315** | **400** | **500** | **630** | **800** | **1000** | **1250** | **1600** | **2000** | **2500** | **3150** | **4000** | **5000** |
| SPL with test tyre (dB) | 71.1 | 77.9 | 80.3 | 87 | 98 | 94.1 | 92.2 | 90.9 | 89.1 | 84 | 80.1 | 78.3 | 74.3 |
| SPL without tyre (dB) | 61.7 | 63.8 | 69.2 | 75.1 | 80.9 | 77.7 | 79.2 | 81.2 | 78.9 | 69.5 | 68.6 | 64.4 | 60 |
| Difference (dB) | 9.4 | 14.2 | 11.2 | 11.9 | 17.1 | 16.3 | 13.1 | 9.7 | 10.2 | 14.5 | 11.5 | 13.9 | 14.3 |
| **At rear microphone** | **Third octave band central frequency (Hz)** | | | | | | | | | | | | |
| | **315** | **400** | **500** | **630** | **800** | **1000** | **1250** | **1600** | **2000** | **2500** | **3150** | **4000** | **5000** |
| SPL with test tyre (dB) | 71.2 | 76 | 78.8 | 85.4 | 95.2 | 93.5 | 93.7 | 92.2 | 87.5 | 83.2 | 79 | 77.6 | 74 |
| SPL without tyre (dB) | 59.1 | 62.7 | 68.3 | 74.9 | 76.4 | 77.9 | 82.3 | 78.7 | 73.6 | 73.5 | 68.5 | 65.5 | 59.7 |
| Difference (dB) | 12.1 | 13.3 | 10.5 | 10.5 | 18.8 | 15.6 | 11.4 | 13.5 | 13.9 | 9.7 | 10.5 | 12 | 14.3 |

According to A.3.3, ISO/DIS 11819-2 for the 'lifted/removed tyre' method when the overall A-weighted level is reduced by at least 10 dB and the third-octave band levels are reduced by at least 6 dB in the 500 – 5000 Hz range (or 4 dB in 315 – 400 Hz) then the requirement above is met. Thus, the results in Table-2 demonstrates that the test CPX trailer satisfies with the performance required in *A.3 (including A.4), ISO/DIS 11819-2.*

### 2.2.3 Background noise from external vehicles (A.5 ISO/DIS 11819-2)

This part of the certification is to judge the influence of noise from external (passing-by) vehicles on the CPX test results. To do this, the test trailer assembly shall be located on the road shoulder where vehicles in the regular traffic can pass the adjacent lane. The average speed of the traffic in the adjacent lane shall be 70-90 km/h and the maximum permitted distance between the test trailer and the adjacent traffic shall be 1.5 m. The road surface for the test shall include a dense asphalt concrete (DAC or SMA) with as fine and dense texture as is available. The traffic conditions on the adjacent lane shall include no less than 20 passenger cars and 10 heavy vehicles (Catergory 2b – trucks buses or coaches with more than 2 axles). If the difference in overall dBA level between this parked trailer scenario and a moving trailer scenario on the same type of road surface at reference speed 80 km/h is equal to or higher than 10 dB, the test vehicle qualifies for use without any special treatment or flagging for passing vehicles in in-traffic measurements, at the reference speed of 80 km/h and higher. The test results are presented in Table 3.

Table 3 – Influence of external vehicles on CPX test

| **At front microphone** | **Third octave band central frequency (Hz)** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **315** | **400** | **500** | **630** | **800** | **1000** | **1250** | **1600** | **2000** | **2500** | **3150** | **4000** | **5000** | **Overall** |
| SPL $L_{Amax}$, CPX park | 68.4 | 71.3 | 71.4 | 77.8 | 79.1 | 79.4 | 78.7 | 74.9 | 72.8 | 67.3 | 64.5 | 65.6 | 62.1 | 86.0 |
| SPL $L_{Amax}$, CPX moving | 74.7 | 81.1 | 83.5 | 90.1 | 100.3 | 96.9 | 94.1 | 92.4 | 90.8 | 85.6 | 81.5 | 80.2 | 77.1 | 103.7 |
| Influence (dB) | 0.9 | 0.4 | 0.3 | 0.2 | 0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| **At rear microphone** | **Third octave band central frequency (Hz)** | | | | | | | | | | | | | |
| | **315** | **400** | **500** | **630** | **800** | **1000** | **1250** | **1600** | **2000** | **2500** | **3150** | **4000** | **5000** | **Overall** |
| SPL $L_{Amax}$, CPX park | 69.7 | 75.6 | 72.3 | 75.8 | 81.5 | 79 | 78.9 | 74.6 | 68.6 | 70.6 | 64 | 66.7 | 68.6 | 86.6 |
| SPL $L_{Amax}$, CPX moving | 74.5 | 78.8 | 81.7 | 88.7 | 98 | 95.7 | 95.6 | 93.6 | 89.1 | 85.4 | 80.6 | 79.3 | 77.2 | 102.6 |
| Influence (dB) | 1.2 | 1.7 | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0 | 0.1 | 0.1 | 0.2 | 0.6 | 0.1 |

The table above shows the overall maximum noise levels at two microphones under the CPX trailer running are 10 dB higher than those measured when the CPX trailer was parked on the road shoulder.

Therefore, the CPX trailer satisfies with the performance required in A.3.5, ISO/DIS 11819-2.

### 2.3 Tyre loads (10.8 ISO/DIS 11819-2)

The static load of the test tyre was measured and the result is 3101 N (316.4 kg). This satisfies with the requirement (3200 ± 200 N) of 10.8 ISO/DIS 11819-2.

## 3. MEASUREMENT SYSTEM

### 3.1 GPS system

To identify the vehicle location and speed during the tests the CPX trailer was equipped with an industrial GPS unit and these physical quantities recorded simultaneously with the noise levels at the microphones.

To ensure the accuracy of the location for the applications here the GPS unit was checked using a photo sensor during the measurements. To do this total of seven optical reflectors were setup on the shoulder of a freeway and an industrial photo sensor was mounted on the trailer to detect the pulse signals from the reflectors. The vehicle speeds were of 100 km/h during the tests and 105 test samples were collected. Figure 2 shows the scatter plots of the GPS position variations. The 95% confidence interval for the GPS position uncertainty is ±1.5 m. This accuracy is sufficient for the ISO/DIS 11819-2 applications because the first 10 m of each test section are discarded for the run-in according to the standard.

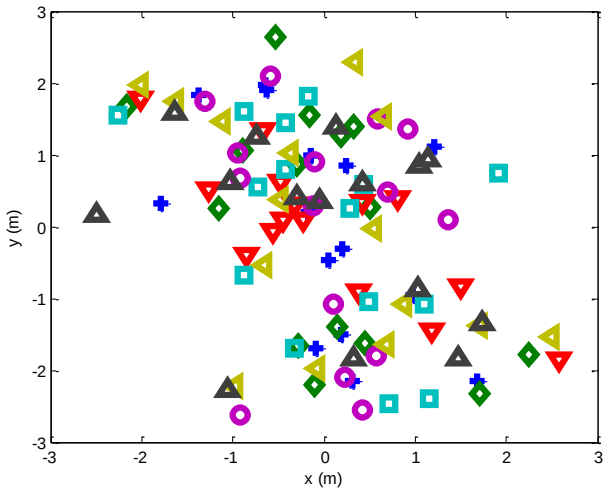



Figure 2 – Scatter plots of the GPS position variation, 105 runs at 100 km/h

### 3.2 OBSI method using current CPX trailer

In the standard of AASHTO TP 76-12 the two measures are implemented to judge the measurement results:

- signal coherence between two microphones on sound intensity probe, and
- PI index

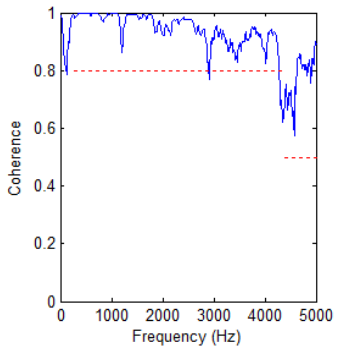
In this section these two measures obtained from a project are evaluated according to AASHTO TP 76-12.

#### 3.2.1 Signal coherence between two microphones on sound intensity probe

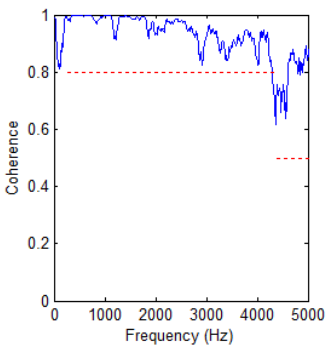
According to the standard of AASHTO TP76-12 the coherence between two microphones on the sound intensity probe shall be at least 0.8 for each one-third octave band between 400 Hz and 4000 Hz and at least 0.5 at 5000 Hz.

Figures 3 – 4 show the typical coherence functions at two intensity probes obtained from a tyre/road noise test project. The test speed was 90 km/h and road pavement was OGA. The sound intensity probes were mounted in accordance with AASHTO TP76-12 with the Vipac CPX trailer. The test tyre is a passenger tyre (Uniroyal M+S 225/60R16, Tigerpaw SRTT).

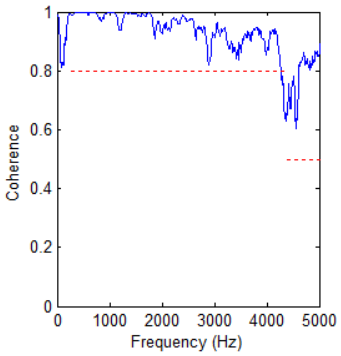
The figures show that the coherence values achieve the requirements above except for those at a few individual frequencies. It is believed that these do not affect the sound intensity calculations over the bands. Consequently, the sound intensity measurements are validated in terms of the evaluation of the coherence functions between microphones on the probe.



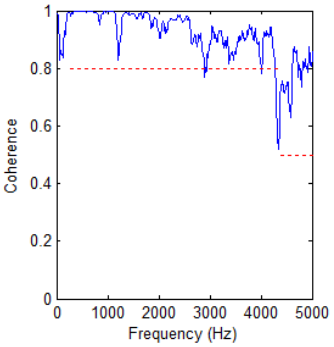

(a) Pavement 1




(b) Pavement 2

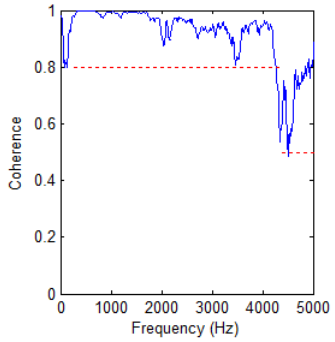



(c) Pavement 3

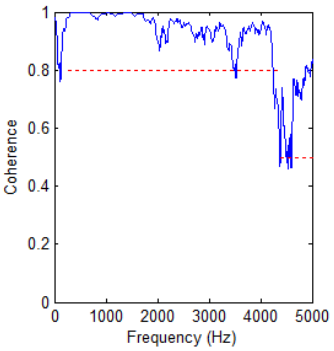



(d) Pavement 4

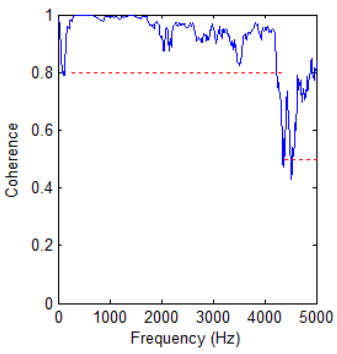
Figure 3 – Coherence functions at front probe for passenger tyre



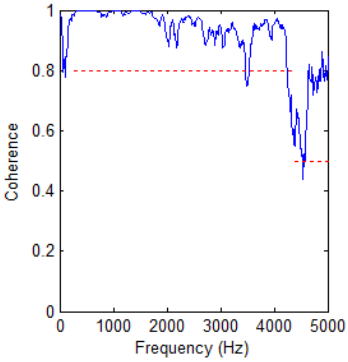

(a) Pavement 1




(b) Pavement 2




(c) Pavement 3



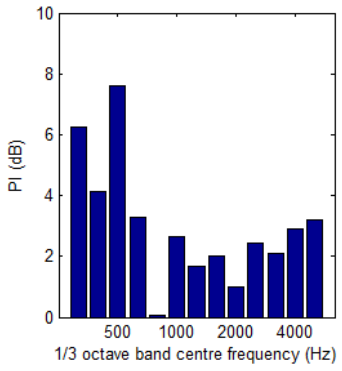

(d) Pavement 4

Figure 4 – Coherence functions at rear probe for passenger tyre

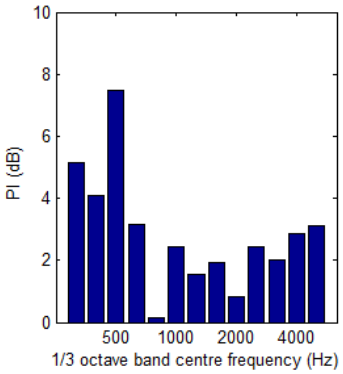
### 3.2.2 PI index

The PI index is a useful guide to grade the accuracy of measurements of the sound intensity. To ensure the accuracy of sound intensity measurement the PI level is limited. In the other words, the sound intensity level in the measurement direction shall be sufficiently high to perform the accurate intensity measurement. In the OBSI method the PI index is limited to less than 5.0 dB according to AASHTO TP76-12.

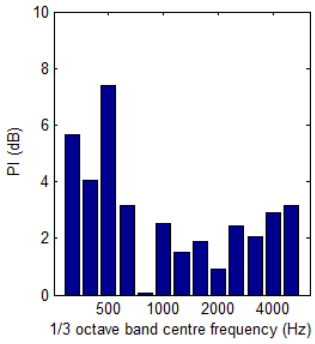
Figures 5 – 6 show the typical PI indexes at two intensity probes. The figures show that PI indices achieve the requirements above except for those at the low frequency range for the front probe. In general the tyre noise levels at low frequency range are not dominant for the overall levels. Consequently, the sound intensity measurements are generally validated in terms of the evaluation of the PI index.



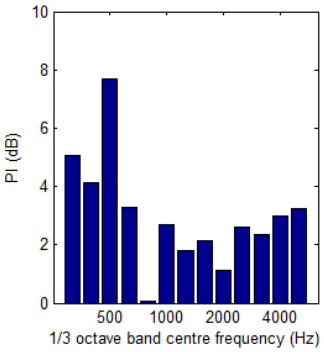

(a) Pavement 1




(b) Pavement 2

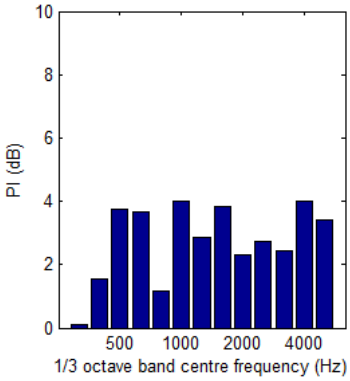



(c) Pavement 3

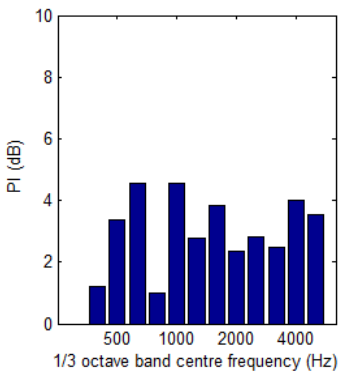



(d) Pavement 4

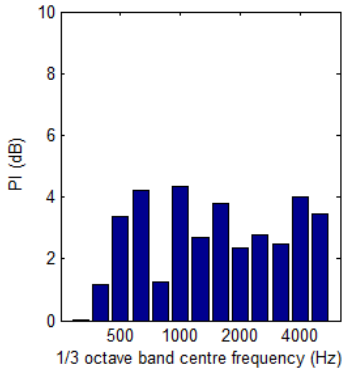
Figure 5 – PI indexes at front probe for passenger tyre



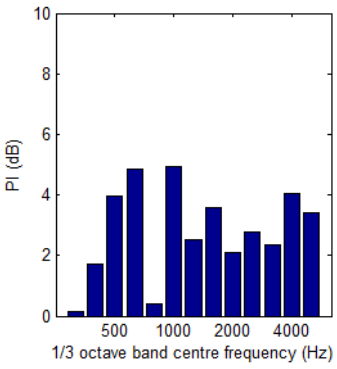

(a) Pavement 1




(b) Pavement 2




(c) Pavement 3




(d) Pavement 4

Figure 6 – PI indexes at rear probe for passenger tyre

## 4. Measurements

The CPX trailer presented above were used for a R&D project to measure tyre/road noise according to ISO/DIS 11819-2 and AASHTO TP76-12. Figures 7 and 8 present the typical $L_{CPX}$ and $L_{OBSI}$ spectra for one of test pavements.

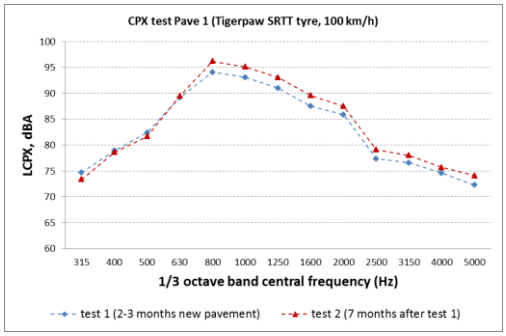



Figure 7 – Average corrected CPX levels for two microphones over ten runs

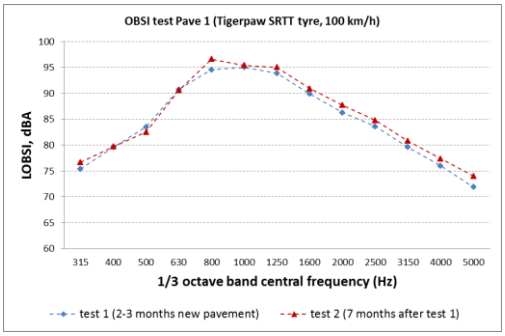



Figure 8 – Average OBSI levels for two probes over ten runs

## 5. CONCLUSIONS

The aim of this paper is to present the procedures and results for the certification of Vipac CPX trailer in accordance with ISO/DIS 11819-2. The results demonstrate that the Vipac CPX trailer satisfies the following performance requirements.

- Sound reflections against an enclosure and other objects near the microphones (A.2 ISO/DIS 11819-2)
- Background noise from the test vehicle itself or its operation (and towing vehicle) (A.3 and A.4 ISO/DIS 11819-2)
- Background noise from external vehicles (A.5 ISO/DIS 11819-2)
- Tyre loads (10.8 ISO/DIS 11819-2)

The evaluations of the OBSI tests using the trailer demonstrate that the trailer satisfies for the OBSI tests in accordance with AASHTO TP76-12.

## REFERENCES

1. ISO/DIS 11819-2 (2012-08-17) Acoustics – Measurement of the influence of road surfaces on traffic noise – Part 2: The close-proximity method
2. AASHTO TP76-12 Measurement of tire/pavement noise using the on-board sound intensity (OBSI) method
3. 30U-12-0144-TRP-331879-0 - Certification of CPX trailer - ISO (CD) 11819-2 , Vipac technical report
4. CPX trailer comparison round robin test data analysis, CROW report D12-02