INTERNATIONAL STANDARD

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Mechanical vibration — Road surface profiles — Reporting of measured data

Vibrations mécaniques — Profils de routes — Méthode de présentation des résultats de mesures

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ISO 8608:2016 https://standards.iteh.ai/catalog/standards/sist/36fa1abb-1fc1-4bd2-a731-3bf32cdc04dc/iso-8608-2016



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see <u>www.iso.org/directives</u>).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition* monitoring, Subcommittee SC 2, Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures. https://standards.iteh.ai/catalog/standards/sist/36fa1abb-1fc1-4bd2-a731-

This second edition cancels and replaces the first edition (ISO) 8608:1995), of which it constitutes a minor revision. The following changes have been made:

- normative references have been updated;
- subclause numbering has been adjusted;
- figures have been made language independent;
- bibliography has been updated;
- editorially revised.

Introduction

The purpose of this document is to facilitate the compilation and comparison of measured vertical road profile data from various sources. It therefore specifies a uniform method of reporting data from one-track and multiple-track measurements.

It specifies how measurements are to be reported, but not how the measurements are to be made. The measuring equipment can influence the results of the measurement; therefore certain characteristics of the measuring system have also to be reported.

<u>Annex A</u> is an example of a report which meets the minimum requirements of this document.

<u>Annex B</u> gives means of approximately characterizing specific road profiles in order to facilitate the division of road profiles into general classifications. A general classification is also given. A curve fitting method is presented for characterizing spectral data.

<u>Annex C</u> provides general guidance for the use of road profile statistical data for simulation studies and for related studies such as evaluation of comfort, suspensions and road profiles.

<u>Annex D</u> discusses the processing of the power spectral density (PSD) with the fast Fourier transform (FFT) technique. A discussion on the statistical precision is also given.

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Mechanical vibration — Road surface profiles — Reporting of measured data

1 Scope

This document specifies a uniform method of reporting measured vertical road profile data for either one-track or multiple-track measurements.

It applies to the reporting of measured vertical profile data taken on roads, streets and highways, and on off-road terrain. It does not apply to rail-track data. Measurement and processing equipment and methods are not included.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61260-1, Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications iTeh STANDARD PREVIEW

3 Terms and definitions(standards.iteh.ai)

For the purposes of this document, the terms and definitions given in ISO 2041 and the following apply. ISO 8608:2016

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at <u>http://www.electropedia.org/</u>

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1 spatial frequency

reciprocal of the wavelength

Note 1 to entry: The spatial frequency is expressed in cycles per metre (cycles/m).

3.2 power spectral density PSD

limiting mean-square value of a signal per unit frequency bandwidth

Note 1 to entry: For a one-sided spectrum, the area located between the graphic plot and the horizontal axis in a linear plot should be equal to the variance σ^2 of the original signal for the evaluated frequency range. This leads to a doubling of the spectral amplitude when the calculation process is only estimating the spectrum for positive frequencies.

3.3

displacement PSD

power spectral density of the vertical road profile displacement

3.4

velocity PSD

power spectral density of the rate of change of the vertical road profile displacement per unit distance travelled (slope of the vertical road profile)

3.5

acceleration PSD

power spectral density of the rate of change of the slope of the vertical road profile per unit distance travelled

3.6

decolouring

procedure to eliminate the influence of the transfer function of the measuring system on the power spectral density

Note 1 to entry: The raw power spectral density should be decoloured before any further processing by dividing it by the square of the modulus of the measuring equipment transfer function.

3.7

smoothing

averaging process in which a data block is shifted and averaged

Note 1 to entry: In this document, "unsmoothed PSD" means the power spectral density as calculated from the measured data, i.e. with the bandwidths used in or following from the calculations and which are different from those indicated in <u>Table 2</u>. The term "smoothed PSD" is the power spectral density which is obtained after using the averaging process described in <u>5.1.2</u>.

4 Symbols

The symbols used in this document are given in Table 1. ITeh STANDARD PREVIEW

(Stanuar us.itch.ar)				
Symbol	Description	Unit		
Be	Frequency resolution SO 8608:2016	cycles/m		
f http	s://standards.iteh.ai/catalog/standards/sist/36fa1abb-1fc1-4 Time frequency_ 3bf32cdc04dc/iso-8608-2016	4bd2-a731- Hz		
<i>G</i> _d (.)	Displacement PSD	m ³		
$G_{\rm V}(.)$	Velocity PSD	m		
G _a (.)	Acceleration PSD	m-1		
<i>G</i> ₁ (.)	PSD of track 1	_		
G ₂ (.)	PSD of track 2	_		
G ₁₂ (.)	Cross spectrum between tracks 1 and 2	—		
1	Wheelbase	m		
п	Spatial frequency	cycles/m		
t	Time	s		
v	Vehicle speed	m/s		
γ^2	Coherence function	_		
σ^2	Variance			
ω	Angular frequency (= $2\pi f$)	rad/s		
Ω	Angular spatial frequency (= $2\pi n$)	rad/m		
NOTE The indication (.) means that the parameter of the function can be spatial frequency (n) or angular spatial frequency (Ω).				

(stable 1 a Symbols h.ai)

5 Uniform method of reporting

5.1 One-track data

5.1.1 Description of the road profile

5.1.1.1 General

The road profile shall be described by one or both of the following methods, with preference for the first, the displacement PSD.

The reporting of the non-smoothed data is always required.

5.1.1.2 First method — Displacement PSD: *G*_d(.)

The road profile shall be described by the power spectral density (PSD) of its vertical displacement. The report shall include the displacement PSD versus (angular) spatial frequency, both on logarithmic axes. The dimensions are metres cubed (m³) versus reciprocal metres (cycles/m and rad/m).

Two scales shall be given on the ordinate, one for $G_d(n)$ and one for $G_d(\Omega)$. Both n and Ω scales shall be indicated in the abscissa. The grid, however, shall only be drawn for $G_d(n)$ and n (see Figure A.2, for example).

5.1.1.3 Second method Acceleration PSD: Ga(.) PREVIEW

The acceleration power spectral density (PSD) is an allowed alternative method of reporting data.

In this case, the road profile shall be described as the PSD of its acceleration in terms of the rate of change of the slope of the road surface percurit*distance travelled. The dimension of the acceleration PSD is reciprocal metres (md1) ds.iteh.ai/catalog/standards/sist/36fa1abb-1fc1-4bd2-a731-

3bf32cdc04dc/iso-8608-2016

The scales shall be logarithmic on both axes. Two scales shall be given on the ordinate, one for $G_a(n)$ and one for $G_a(\Omega)$. On the abscissa, both n and Ω shall be indicated. The grid, however, shall only be drawn for $G_a(n)$ and n.

5.1.1.4 Relationship between the two reporting methods

The relationship between the two reporting methods (see 5.1.1.2 and 5.1.1.3) is given by Formulae (1) and (2):

$G_{\rm a}(n) = (2\pi n)^4 \cdot G_{\rm d}(n)$	(1)

5.1.1.5 Spatial frequency range

 $G_{a}(\Omega) = \Omega^{4} \cdot G_{d}(\Omega)$

The reported PSD shall be restricted between the limits allowed by the measuring equipment. For the report, the user may select any spatial frequency range appropriate to his/her particular road surface, problem and product.

The measured surface depends on the measuring equipment, which has a certain smoothing effect. This equipment is to be reported (see Note 4 and 5.3.5.2.1).

NOTE 1 Figure C.1 gives the relationship between the vehicle speed, the spatial frequency and the time frequency. Knowledge of the frequency and speed characteristics for a given class of vehicles makes it possible to choose the useful limits for that class of vehicle (e.g. on-road or off-road vehicles).

(2)

NOTE 2 For the lower limit, the spatial frequency need not in general be measured lower than 0,01 cycles/m for on-road vehicles and 0,05 cycles/m for off-road vehicles.

NOTE 3 The enveloping effect of the tyre acts as a low-pass filter for the road vibration input to the vehicle. This effect depends on the size and construction of the tyre. For general on-road measurements, this results in a recommended upper limit of 10 cycles/m. Of course for suspension vibration purposes, the interesting upper limit depends on the maximum allowed speed on the particular road. For noise purposes, the interesting upper limit may be much higher, and may go as high as 1 000 cycles/m.

NOTE 4 Due to the tyre width there is also an enveloping effect in the lateral direction. This means that for vibration purposes, the mean of the footprint is usually measured. The width depends on the problem (e.g. vibration, noise) and the product (e.g. motorcycle tyres, truck tyres). For general on-road measurements not intended for a specific product, a track of about 100 mm wide is often used for vibration purposes. For noise purposes, a point measurement is often used.

NOTE 5 For off-road measurements, care needs to be taken when interpreting the high frequencies. For soft (e.g. sandy) surfaces, short undulations could be flattened by the wheel load and filtered out. For hard (e.g. stone) surfaces, however, only the enveloping effect of the tyre acts as a filter. In this situation, the surface needs to be described accurately in the data sheet (see <u>5.3.5.3.2</u>).

NOTE 6 Annex B gives recommended methods for the characterization of the road profile and for the fitting of the measured data.

5.1.2 Presentation of the smoothed power spectral density

When the power spectral densities are calculated with a constant bandwidth method, their representation in a log-log diagram give an appearance or visual impression at high frequencies which over-emphasizes the fluctuations of the PSD generated by the real power distribution and by the statistical noise. **(standards.iteh.ai)**

For this reason, the PSD shall also be represented in a smoothed form, i.e. by the mean PSD in the following frequency bands:

- https://standards.iteh.ai/catalog/standards/sist/36fa1abb-1fc1-4bd2-a731-
- octave bands from the lowest calculated frequency (except zero) up to a centre frequency of 0,031 2 cycles/m (0,196 3 rad/m);
- one-third-octave bands from the last octave band up to a centre frequency of 0,25 cycles/m (1,570 8 rad/m);
- for the rest of the frequency range, one-twelfth-octave bands up to the highest calculated frequency.

The centre frequencies to be used for the calculation of the smoothed PSD are given in <u>Table 2</u>.

Fable 2 — Centre frequencies and cut-off frequencies for PSD smoothing,	
expressed in spatial frequency n	

Exponent EXP	Lower cut-off frequency n _l cycles/m	Centre frequency $n_{\rm c} = 2^{\rm EXP}$ cycles/m	Upper cut-off frequency n _h cycles/m		
Octave bands					
-9	0,001 4	0,002 0	0,002 8		
-8	0,002 8	0,003 9	0,005 5		
-7	0,005 5	0,007 8	0,011 0		
-6	0,011 0	0,015 6	0,022 1		
-5	0,022 1	0,031 2	0,044 2		

EXP n cycles/m ne = 2EXP cycles/m nh cycles/m -4.333 0.044 2 0.049 6 0.055 7 -4 0.055 7 0.062 5 0.070 2 -3,667 0.070 2 0.078 7 0.088 4 -3,333 0.088 4 0.099 2 0.111 4 -3 0.111 4 0.125 0 0.140 3 -2,667 0.140 3 0.157 5 0.176 8 -2,333 0.076 8 0.198 4 0.222 7 -2 0.222 7 0.250 0 0.280 6 -1,833 0.272 6 0.280 6 0.288 8 -1,750 0.288 8 0.297 3 0.306 0 -1,667 0.306 0 0.315 0 0.324 2 -1,583 0.324 2 0.333 7 0.343 5 -1,417 0.436 39 0.437 4 0.438 6 -1,250 0.408 5 0.420 4 0.432 8 -1,167 0.363 9 0.374 6 0.435 4 -1,083 0.9458 0.055 0.648 4 0.667 2 -1,0485	Exponent	Lower cut-off frequency	Centre frequency	Upper cut-off frequency
-4,333 0,044 2 0,049 6 0,055 7 -4 0,055 7 0,062 5 0,070 2 -3,667 0,070 2 0,078 7 0,088 4 -3,333 0,088 4 0,099 2 0,111 4 -3 0,111 4 0,125 0 0,140 3 -2,667 0,140 3 0,157 5 0,176 8 -2,333 0,176 8 0,198 4 0,222 7 -2 0,222 7 0,250 0 0,280 6 -1,833 0,272 6 0,280 6 0,386 6 -1,667 0,306 0 0,315 0 0,324 2 -1,583 0,324 2 0,333 7 0,334 5 -1,590 ST 4,343 9 ARD P0358 (VIEW 0,363 9 -1,470 0,363 9 0,374 6 0,335 6 -1,250 0,408 5 0,420 4 0,432 8 -1,167 0,363 9 0,374 6 0,385 6 -1,167 0,438 5 0,420 4 0,432 8 -1,167 0,438 5 0,561 2 0,577 7 -0,917 0,514 7 <td>EXP</td> <td>$n_{\rm l}$ cycles/m</td> <td>$n_{\rm c} = 2^{\rm EXP}$ cycles/m</td> <td>n_h cycles/m</td>	EXP	$n_{\rm l}$ cycles/m	$n_{\rm c} = 2^{\rm EXP}$ cycles/m	n _h cycles/m
-4,333 0,044 2 0,049 6 0,055 7 -4 0,055 7 0,062 5 0,070 2 -3,667 0,070 2 0,078 7 0,088 4 -3,333 0,088 4 0,099 2 0,111 4 -3 0,111 4 0,125 0 0,140 3 -2,667 0,140 3 0,157 5 0,176 8 -2,333 0,176 8 0,280 6 0,280 6 -2,333 0,176 8 0,280 6 0,280 6 -1,833 0,272 6 0,220 6 0,306 0 -1,667 0,306 0 0,315 0 0,324 2 -1,583 0,324 2 0,333 7 0,343 5 -1,590 eh ST 4,3435 ARD P058 (FFW) 0,363 9 0,343 5 -1,503 0,324 2 0,333 7 0,343 5 -1,250 0,408 5 0,420 4 0,432 8 -1,250 0,408 5 0,420 4 0,435 5 -1,0485 8 0,5 0,514 7 0,485 8 -0,917 0,514 7 0,529 7 0,545 3 -0,667		One-third-	octave bands	eyeres/ m
-4 $0,0557$ $0,0625$ $0,0702$ $-3,667$ $0,0702$ $0,0787$ $0,0884$ $-3,333$ $0,0884$ $0,0992$ $0,1114$ -3 $0,1114$ $0,1250$ $0,1403$ $-2,667$ $0,1403$ $0,1575$ $0,1768$ $-2,333$ $0,1768$ $0,1984$ $0,2227$ -2 $0,2227$ $0,2500$ $0,2806$ One-twelfth-octave bands $-1,633$ $0,2726$ $0,2806$ $0,33600$ $-1,667$ $0,3060$ $0,3150$ $0,3242$ $-1,583$ $0,3242$ $0,3337$ $0,3435$ $-1,507$ $0,32849$ $0,3746$ $0,3856$ $-1,333$ (STA,3435) ARD P0556 VIEW $0,3639$ $0,3746$ $-1,417$ $0,3639$ $0,4726$ $0,4454$ $-1,677$ $0,4858$ $0,4204$ $0,4328$ $-1,2500$ $0,4985$ $0,4204$ $0,4328$ $-1,250$ $0,4985$ $0,452$ $0,5147$ $-0,917$ $0,5147$ $0,5297$ $0,5147$ $-0,917$ $0,5147$ $0,5297$ $0,5453$ $-0,667$ $0,6120$ $0,6300$ $0,6484$ $-0,583$ $0,64844$ $0,6674$ $0,6870$ $-0,510$ $0,6777$ $0,5946$ $0,6120$ $-0,667$ $0,6120$ $0,7971$ $0,7711$ $-0,533$ $0,7711$ $0,7937$ $0,8170$ $-0,583$ $0,64844$ $0,6674$ $0,6870$ $-0,617$ $0,8655$ $0,8909$ $0,9170$ $-0,683$ $0,9170$ $0,$	-4.333	0.044.2	0.049.6	0.055.7
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1,7500,288 80,297 30,306 0-1,7500,288 80,297 30,306 0-1,6670,306 00,315 00,324 2-1,5830,324 20,333 70,343 5-1,5070,363 90,374 60,363 9-1,4170,363 90,374 60,385 6-1,333(Stable ards, itel,396)0,408 5-1,2500,408 50,420 40,432 8-1,1670,432 80,420 40,432 8-1,1670,432 80,50,514 7-1,08339438 5)4dc/iso 8608-29471 90,485 8-10,485 80,50,514 7-0,9170,514 70,529 70,545 3-0,8330,545 30,561 20,577 7-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,226 80,4171,296 81,334 81,374 00,5001,374 01,414 2	-1 833	0 272 6	0 280 6	0 288 8
1,6670,306 00,315 00,324 2-1,5830,324 20,333 70,343 5-1,507 ehST 0,335 ARD P0358 6/IE0,363 9-1,4170,363 90,374 60,363 90,374 6-1,333(st 0,326 ard s,ite 0,396)0,408 5-1,2500,408 50,420 40,432 80,445 4-1,1670,432 80,445 80,445 4-1,08330458 50466/sst 264 40/sst 264 161-402-4731-1,08330458 50466/sst 264 161-402-4731-0,9170,514 70,9170,514 70,7500,577 70,7500,577 70,594 60,612 0-0,6670,612 00,6670,612 00,6670,612 00,480 90,865 5-0,1670,887 0-0,2500,817 00,817 00,943 90,971 5100,971 511,029 30,0831,029 31,059 51,090 50,1671,090 50,122 51,155 40,2501,155 40,2501,155 40,2501,155 40,2501,155 40,2501,155 40,2501,155 40,2501,155 40,2501,155 40,2501,155 40,2501,374 00,4171,296 80,3331,224 10,5831,455 70,5831,455 70,5831,455 7<	-1 750	0 288 8	0 297 3	0 306 0
1,0070,000 00,010 00,010 0-1,5830,324 20,333 70,343 5-1,500 eh $ST 4,3435 ARD P0358 6VIEW$ 0,363 9-1,4170,363 90,374 60,385 6-1,333(stable endsite b396 9)0,408 5-1,2500,408 50,420 40,432 8-1,1670,432 80,808 20160,445 4-1,0830,445 80,50,514 7-0,9170,514 70,529 70,545 3-0,8330,545 30,561 20,577 7-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-1 667	0 306 0	0 315 0	0 324 2
1,5000,51120,50570,5057 $-1,500$ ST 4 ,3435 ARD P0358 6VIEW 0,363 9 $-1,417$ 0,363 90,374 60,385 6 $-1,333$ (ST 0 ,865 6 ards.iteb ,3969)0,408 5 $-1,250$ 0,408 50,420 40,432 8 $-1,167$ 0,432 80,608 20160,445 4https://standards.iste/aircaluo/standards/ist/3611 abrol-161-4bc2-a7310,458 5 $-1,083$ 39,458 50 446/iso8608-29,471 9 -1 0,485 80,50,514 7 $-0,917$ 0,514 70,529 70,545 3 $-0,833$ 0,545 30,561 20,577 7 $-0,750$ 0,577 70,594 60,612 0 $-0,667$ 0,612 00,630 00,648 4 $-0,583$ 0,648 40,667 40,687 0 $-0,500$ 0,687 00,707 10,727 8 $-0,417$ 0,727 80,749 20,771 1 $-0,250$ 0,817 00,840 90,865 5 $-0,167$ 0,865 50,890 90,917 0 $-0,083$ 0,917 00,943 90,971 5 0 0,971 511,029 3 $0,083$ 1,029 31,059 51,090 5 $0,167$ 1,090 51,122 51,155 4 $0,250$ 1,155 41,189 21,224 1 $0,333$ 1,224 11,259 91,296 8 $0,417$ 1,296 81,334 81,374 0 $0,500$ 1,374 01,414 21,455 7 $0,583$ 1,455 71,498 31,542 2 <td>-1 583</td> <td>0 324 2</td> <td>0 333 7</td> <td>0 343 5</td>	-1 583	0 324 2	0 333 7	0 343 5
1.4170.363 90.374 60.385 6-1,4170.363 90.374 60.385 6-1,333(Stabsed Ids itelesisted sitelesisted and sitelesis			D D 358 6 7 1 D	
-1,333 (sta)ses and site based 0,408 5 -1,250 0,408 5 0,420 4 0,432 8 -1,167 0,432 8 0,432 8 0,432 8 -1,083 30,458 5 0,420 4 0,432 8 -1,083 30,458 5 0,420 4 0,438 5 -1083 30,458 5 0,458 5 0,417 -0,917 0,514 7 0,529 7 0,545 3 -0,833 0,545 3 0,561 2 0,577 7 -0,750 0,577 7 0,594 6 0,612 0 -0,667 0,612 0 0,630 0 0,648 4 -0,583 0,648 4 0,667 4 0,687 0 -0,500 0,687 0 0,707 1 0,727 8 -0,417 0,727 8 0,749 2 0,771 1 -0,250 0,817 0 0,840 9 0,865 5 -0,167 0,865 5 0,890 9 0,917 0 -0,083 0,917 0 0,943 9 0,971 5 0 0,971 5 1 1,029 3 0,083 1,029 3 1,059 5 1,090 5 0,167 1,090 5 1,122 5 <td>-1 417</td> <td>0 363 9</td> <td>0 374 6</td> <td>0 385 6</td>	-1 417	0 363 9	0 374 6	0 385 6
1,353 $(1-0,36)$ or $(1-0)$ $(0,35)$ $(0,16)$ or $(1-0)$ -1,250 $0,408$ 5 $0,420$ 4 $0,432$ 8-1,167 $0,432$ 8 $0,432$ 8 $0,4454$ $0,432$ 8-1,083 $30,458$ 504dc/iso $8608-20,471$ 9 $0,485$ 8-1 $0,485$ 8 $0,5$ $0,514$ 7-0,917 $0,514$ 7 $0,529$ 7 $0,545$ 3-0,833 $0,545$ 3 $0,561$ 2 $0,577$ 7-0,750 $0,577$ 7 $0,594$ 6 $0,612$ 0-0,667 $0,612$ 0 $0,630$ 0 $0,648$ 4-0,583 $0,648$ 4 $0,667$ 4 $0,687$ 0-0,500 $0,687$ 0 $0,707$ 1 $0,727$ 8-0,417 $0,727$ 8 $0,749$ 2 $0,771$ 1-0,250 $0,817$ 0 $0,840$ 9 $0,865$ 5-0,167 $0,865$ 5 $0,890$ 9 $0,917$ 0-0,083 $0,917$ 0 $0,943$ 9 $0,971$ 50 $0,971$ 51 $1,029$ 3 $0,083$ $1,029$ 3 $1,059$ 5 $1,090$ 5 $0,167$ $1,900$ 5 $1,122$ 5 $1,155$ 4 $0,250$ $1,155$ 4 $1,189$ 2 $1,224$ 1 $0,333$ $1,224$ 1 $1,259$ 9 $1,296$ 8 $0,417$ $1,296$ 8 $1,334$ 8 $1,374$ 0 $0,500$ $1,374$ 0 $1,414$ 2 $1,455$ 7 $0,583$ $1,455$ 7 $1,498$ 3 $1,542$ 2	_1 333	(standards		0 408 5
1,1500,1600,1600,1600,1600,160-1,1670,4320,4320,44540,44540,4858-10,48580,50,51470,4858-0,9170,51470,52970,5453-0,8330,54530,56120,5777-0,7500,57770,59460,6120-0,6670,61200,63000,6484-0,5830,64840,66740,6870-0,4170,72780,70710,7278-0,4170,72780,84090,8655-0,1670,86550,89090,9170-0,0830,91700,94390,9170-0,0830,917511,02930,0831,02931,05951,090500,971511,02930,0831,02931,25991,22410,3331,22411,25991,29680,4171,29681,33481,37400,5001,37401,41421,45570,5831,45571,49831,5422	-1 250	0 408 5	0 420 4	0.432.8
http://standards.itch.add.bis/standards/sist/3651405-1fc1-4bd2-a7310,485 8-10,485 80,50,514 7-0,9170,514 70,529 70,545 3-0,8330,545 30,561 20,577 7-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	_1 167	0.432	2016 0.445.4	0,458 5
1,00038132420442750 808-2047 1 90,100 0-10,485 80,50,514 7-0,9170,514 70,529 70,545 3-0,8330,545 30,561 20,577 7-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,3330,771 10,793 70,817 0-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	https://standar	ds.iteh.ai/catalog/standard	s/sist/36fa1abb-1fc1-4bd	2-a731- 0.485.8
-0,9170,514 70,529 70,545 3-0,8330,545 30,561 20,577 7-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	_1	0 485 8	-8608-2016 1 9	0 514 7
-0,8330,545 30,561 20,577 7-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.917	0 514 7	0 529 7	0 545 3
-0,7500,577 70,594 60,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,3330,771 10,793 70,817 0-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.833	0 545 3	0,561.2	0,577.7
0,7300,677 70,671 00,612 0-0,6670,612 00,630 00,648 4-0,5830,648 40,667 40,687 0-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,3330,771 10,793 70,817 0-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.750	0 577 7	0 594 6	0,612.0
0,0070,012.00,032.00,032.00,012.1-0,5830,648.40,667.40,687.0-0,5000,687.00,707.10,727.8-0,4170,727.80,749.20,771.1-0,3330,771.10,793.70,817.0-0,2500,817.00,840.90,865.5-0,1670,865.50,890.90,917.0-0,0830,917.00,943.90,971.500,971.511,029.30,0831,029.31,059.51,090.50,1671,090.51,122.51,155.40,2501,155.41,189.21,224.10,3331,224.11,259.91,296.80,4171,296.81,334.81,374.00,5001,374.01,414.21,455.70,5831,455.71,498.31,542.2	-0.667	0,612.0	0,630.0	0,648.4
-0,5030,640 f0,607 f0,607 f-0,5000,687 00,707 10,727 8-0,4170,727 80,749 20,771 1-0,3330,771 10,793 70,817 0-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.583	0.648.4	0,657.4	0,687.0
-0,4170,727 80,749 20,771 1-0,3330,771 10,793 70,817 0-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.500	0.687.0	0 707 1	0,727.8
-0,1170,727 00,747 20,711-0,3330,771 10,793 70,817 0-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.417	0.727.8	0 749 2	0,727 0
-0,2500,817 00,840 90,865 5-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0 333	0 771 1	0 793 7	0.817.0
-0,1670,865 50,890 90,917 0-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.250	0.817.0	0.840.9	0.865.5
-0,0830,917 00,943 90,971 500,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.167	0.865.5	0 890 9	0,005 5
00,971 511,029 30,0831,029 31,059 51,090 50,1671,090 51,122 51,155 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	-0.083	0.917.0	0.943.9	0.971 5
0,083 1,029 3 1,059 5 1,090 5 0,167 1,090 5 1,122 5 1,155 4 0,250 1,155 4 1,189 2 1,224 1 0,333 1,224 1 1,259 9 1,296 8 0,417 1,296 8 1,334 8 1,374 0 0,500 1,374 0 1,414 2 1,455 7 0,583 1,455 7 1,498 3 1,542 2	0,005	09715	1	1 029 3
0,0001,02701,03701,07030,1671,09051,12251,15540,2501,15541,18921,22410,3331,22411,25991,29680,4171,29681,33481,37400,5001,37401,41421,45570,5831,45571,49831,5422	0.083	1 029 3	1 059 5	1 090 5
0,1071,050 01,122 01,133 40,2501,155 41,189 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	0.167	1 090 5	1 1 2 2 5	1 155 4
0,2331,224 11,109 21,224 10,3331,224 11,259 91,296 80,4171,296 81,334 81,374 00,5001,374 01,414 21,455 70,5831,455 71,498 31,542 2	0.250	1 155 4	1 189 2	1 224 1
0,5001,22111,25771,25000,4171,29681,33481,37400,5001,37401,41421,45570,5831,45571,49831,5422	0,230	1 224 1	1 259 9	1 296 8
0,500 1,374 0 1,414 2 1,455 7 0,583 1,455 7 1,498 3 1,542 2	0 417	1 296.8	1 334 8	1 374 0
0,583 1,455 7 1,498 3 1,542 2	0,500	1 374 0	1 414 2	1 455 7
1,1007 1,1700 1,074 2	0.583	1 455 7	1 498 3	1 542 2
0.667 1.542.2 1.587.4 1.622.0	0,555	1 542 2	1 587 /	1 622 0

 Table 2 (continued)

Exponent	Lower cut-off frequency	Centre frequency	Upper cut-off frequency
EXP	n_{l}	$n_{\rm c} = 2^{\rm EXP}$	n _h
	cycles/m	cycles/m	cycles/m
0,750	1,633 9	1,681 8	1,731 1
0,833	1,731 1	1,781 8	1,834 0
0,917	1,834 0	1,887 7	1,943 1
1	1,943 1	2	2,058 6
1,083	2,058 6	2,118 9	2,181 0
1,167	2,181 0	2,244 9	2,310 7
1,250	2,310 7	2,378 4	2,448 1
1,333	2,448 1	2,519 8	2,593 7
1,417	2,593 7	2,669 7	2,747 9
1,500	2,747 9	2,828 4	2,911 3
1,583	2,911 3	2,996 6	3,084 4
1,667	3,084 4	3,174 8	3,267 8
1,750	3,267 8	3,363 6	3,462 1
1,833	3,462 1	3,563 6	3,668 0
1,917	Teh3,6680	AR3,775 DRF	3,886 1
2	3,886 1	4	4,117 2
2,083	4, 1,1%5and	ard <u>ş,2</u> 379h.aı	4,362 0
2,167	4,362 0	4,489 8	4,621 4
2,250 https	4,621 4.	<u>0 8608;2016</u> 4,756.8	4,896 2
2,333	4,896 23bf32cdd	:04dc/is5-8608-72016	5,187 4
2,417	5,187 4	5,339 4	5,495 8
2,500	5,495 8	5,656 9	5,822 6
2,583	5,822 6	5,993 2	6,168 8
2,667	6,168 8	6,349 6	6,535 7
2,750	6,535 7	6,727 2	6,924 3
2,833	6,924 3	7,127 2	7,336 0
2,917	7,336 0	7,551 0	7,772 3
3	7,772 3	8	8,234 4
NOTE A small o	verlap exists betwee	n the lowest one-twe	lfth-octave band and

 Table 2 (continued)

NOTE A small overlap exists between the lowest one-twelfth-octave band and the highest one-third-octave band. This overlap maintains the values 0,5; 1; 2; 4 as centre frequencies in the one-twelfth-octave bands. This makes it convenient to calculate the road characterization (see $\underline{B.4}$) immediately from the one-twelfth-octave band smoothing.

The mean PSD in a defined band should be calculated as given by Formula (3):

$$G_{s}(i) = \frac{\left[\left(n_{\rm L}+0,5\right) \cdot B_{\rm e}-n_{\rm l}(i)\right] G\left(n_{\rm L}\right) + \sum_{j=n_{\rm L}+1}^{n_{\rm H}-1} G\left(j\right) \cdot B_{\rm e} + \left[n_{\rm h}(i) - \left(n_{\rm H}-0,5\right) \cdot B_{\rm e}\right] G\left(n_{\rm H}\right)}{n_{\rm h}(i) - n_{\rm l}(i)}$$
(3)

where

 $G_{\rm S}(i)$ is the smoothed PSD in smoothing band *i*;

$$n_{\rm H} = {\rm INT}\left(\frac{n_{\rm h}(i)}{B_{\rm e}} + 0.5\right)$$
 (*n*_h: see Table 2);

$$n_{\rm L} = {\rm INT}\left(\frac{n_{\rm l}(i)}{B_{\rm e}} + 0, 5\right)$$
 (*n*_l: see Table 2).

The other symbols are as defined in <u>Table 1</u>. INT is the integer function.

The first and the third terms of the right hand side of Formula (3), respectively, calculate the parts of the original $n_{\rm L}$ and $n_{\rm H}$ in the calculated smoothing band *i*.

If this scheme cannot be followed, due to the calculations, the differences shall be noted in the report. The same rules shall be followed when the smoothing is to be done in angular spatial frequency.

The same rules shall be followed for analogue computation.

A small and easy supplementary calculation following the processing of the smoothed PSD leads to the characterization of the road profile as described in <u>Annex Bbb-1fc1-4bd2-a731-</u>

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5.2 Multiple-track data

The multiple-track road profile data shall be described as the PSD curves of each track as described in 5.1, and their relationship curves expressed as their coherence function [see Formula (4)].

$$\gamma^2 = \frac{G_{12}^2(.)}{G_1(.) \cdot G_2(.)} \tag{4}$$

When more than two tracks are measured, the most travelled track near the edge of the road shall be taken as the reference track for the calculation of coherence functions.

The curve shall be smoothed as described in 5.1.2.

5.3 Report

5.3.1 General

The report shall contain one or more curve sheets and general information.

5.3.2 One-track data curve sheet

The curve sheet for one-track data shall contain the non-smoothed PSD and the smoothed PSD. When the information is given on one sheet, the separate curves should be carefully differentiated.

The PSD curve sheet shall also include the information given in 5.3.4.1.3, 5.3.4.1.4, 5.3.4.1.5, 5.3.5.3.1 and 5.3.5.3.2.