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Materials Science and Technology

Comparison of CNOSSOS-EU (Rail) & sonRAIL

Imprint

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Contents

Abstract

The European CNOSSOS-EU model describes a railway noise emission calculation method and proposes default input parameters. The current Swiss railway noise engineering model sonRAIL also consists of a calculation method and a corresponding source database derived from measurement campaigns in Switzerland. This report compares the two models formally and by emission calculation results. The model structures of sonRAIL and CNOSSOS-EU are found to be very similar since both base on previously published railway noise source models. Differences between the models are identified in their detailed descriptions. For the most relevant noise source, i.e. rolling noise, the calculations are nearly coincident. Apart from that, sonRAIL is more detailed in the description of secondary sources like traction noise, whereas for impact noise CNOSSOS-EU is closer to the physical mechanisms. It is demonstrated that these differences only minimally affect the overall A-weighted emission levels in the standard geometry. In shielded geometries, differences in source directivity may lead to 1.5 dB lower to 0.5 dB higher rolling and impact noise emissions for sonRAIL as compared to CNOSSOS-EU, neglecting possible compensating propagation model differences. With the model's default parameter settings considerable differences of multiple dB between the models were found. However using Swiss input data, average differences between emission calculations with the sonRAIL model and the CNOSSOS-EU model for rolling and impact noise are below 1 dB. This leads to the conclusion that sonRAIL has a high level of conformity with CNOSSOS-EU.

1 Mandate

By contract from 1.5.2019 the Laboratory for Acoustics/Noise Control at Empa, the Swiss Federal Laboratories for Materials Science and Technology, was mandated by the Swiss Federal Office for the Environment (FOEN) to conduct a study on railway noise emission modeling (Empa project number 5214.021934). This involved comparisons of the two railway noise engineering emission models CNOSSOS-EU and sonRAIL regarding model structure and calculation results of relevant exposure cases. These comparisons were made with the goal to assess the conformity of sonRAIL with CNOSSOS-EU.

2 Introduction

In 2002 the Environmental noise directive (END) [1] on the assessment and management of environmental noise was adopted in the European Union (EU). Its original annex II about the assessment methods describes the adaptation of national computation methods.

The research project sonRAIL ran during the years 2007 to 2009 and was funded by FOEN and led by Empa, the Swiss Federal Laboratories for Materials Science and Technology. It involved extensive measurements on the Swiss rail network capturing regular traffic as well as two specifically composed measurement trains, and the resulting data was used to develop a new Swiss railway emission model. This model, henceforth referred to as *sonRAIL*, was published in 2010 [2, 3] and consists of a calculation method and a corresponding source database.

In 2015 the EU published the CNOSSOS-EU model [4] as a replacement of annex II of the END [1] which among other noise sources describes a railway noise emission model. A corrigendum to CNOSSOS-EU was published in 2018 [5], henceforth referred to as *CNOSSOS*. CNOSSOS describes a railway noise emission calculation method [4] and proposes default values for the model parameters in a source database [5]. However, [4] states that in the application of the method, the input data shall reflect the actual usage and that in general there shall be no reliance on default input values.

This report summarises the results of comparisons of the two railway noise emission models sonRAIL and CNOSSOS. These comparisons are used to assess the conformity of sonRAIL with CNOSSOS. The report is structured as follows: Section 3 formally compares the two models with respect to model structure, formulas and definitions and points out and discusses similarities and differences between them. Section 4 contains calculation results of sound emission levels for relevant cases. Comparisons using the model default input parameters are presented in Section 4.1 followed by comparisons with Swiss input data in Section 4.2. Conclusions are drawn in the final Section 5.

3 Model comparison

3.1 Model types

CNOSSOS and sonRAIL are models of the same abstraction level and of the same model type. As a basis, both models describe the sound emissions of single rail vehicles, such as locomotives and freight wagons. Considering train fleets and compositions, travelling speeds and traffic flows, the sound emissions of equivalent line source segments are calculated as sound power per metre $L_{W'}$. Both models are frequency domain models operating in a 1/3 octave band resolution. The calculated spectral sound emission contributions are weighted and summed up to obtain A-weighted emission levels. Both models separately describe different physical railway noise sources, such as rolling, impact and traction noise, and attribute the calculated emissions to equivalent sound source locations and sum them up energetically, as a starting point for the subsequent propagation calculation. Both models distribute the equivalent sources vertically, i.e. at different source heights, at the center of each track.

The model structures of sonRAIL and CNOSSOS are very similar since they both base on previously published railway source models such as Harmonoise [6] and IMAGINE [7]. In most Swiss railway noise exposure situations, rolling noise is the dominant noise source. In both models, rolling noise emissions are calculated in dependence of the vehicle and the track characteristics. Both models follow a STAIRRS Level 2 approach [8] with an independent characterisation of track and vehicle by separate transfer functions and surface roughness spectra of wheels and rails.

3.2 Differences in model description

But still some differences between sonRAIL and CNOSSOS can be identified in their detailed description. The most apparent differences are elaborated and discussed in the following.

3.2.1 Source description

Whereas CNOSSOS only distinguishes two vertically stacked equivalent line sources, sonRAIL uses five different source heights to represent the vertical source extension of the rail vehicle. CNOSSOS foresees two source heights at 0.5 and 4 m, respectively, above rail head. sonRAIL has sources at 0, 0.5, 2, 3 and 4 m above rail head. Rolling, impact, curve and bridge noise are attributed to the lower source in CNOSSOS, and split between the two lowest sources in sonRAIL according to their physical location. Traction and aerodynamic noise are distributed between the source heights in both models. sonRAIL is thus more detailed with respect to source distribution. To facilitate comparisons between the models, the presented emissions are accumulated over the source heights.

Whereas sonRAIL keeps the 1/3 octave band frequency resolution, CNOSSOS reduces the frequency resolution of the derived sound power levels L_W to octave bands prior to aggregation to section-wise $L_{W'}$ and the propagation calculation. The numerical comparisons in Section 4 are however made in the full 1/3 octave band resolution.

The two models slightly differ with respect to their considered frequency range. CNOSSOS considers 24 1/3 octave bands from 50 Hz to 10 kHz whereas sonRAIL considers 20 1/3 octave bands from 100 Hz to 8 kHz.

3.2.2 Source directivity

CNOSSOS specifies a directional sound power level $L_{W,\mathrm{dir}}$ that is calculated from the sound power level L_W using a vertical and a horizontal directivity correction by

$$L_{W,\mathrm{dir}}(\psi,\varphi) = L_W + \Delta L_{W,\mathrm{dir,vert}}(\psi) + \Delta L_{W,\mathrm{dir,hor}}(\varphi), \tag{1}$$

with the polar angles ψ and φ. For many sources, like rolling and impact noise, CNOSSOS suggests for the horizontal directivity $\Delta L_{W,\mathrm{dir,hor}}$ by default a dipole characteristics with maximum radiation perpendicular to the track as depicted in Fig. 1. The proposed vertical directivity $\Delta L_{W,\mathrm{dir,vert}}$ in CNOSSOS depends on the source location and on frequency. The vertical directivity of CNOSSOS for rolling and impact noise is illustrated in Fig. 2. It amounts to 0 dB at rail level (0° elevation) and has a local maximum at an elevation angle of about 24° with amplifications from 0.6 dB at 50 Hz to 2 dB at 10 kHz. The CNOSSOS expressions for non-uniform directivities are not energy-neutral and thus the CNOSSOS source descriptions are inconsistent with the basic definition of the physical quantity sound power. Therefore the calculation comparisons in Section 4 rely on representative emission sound pressure levels instead of sound power levels.

In contrast, sonRAIL generally assumes omnidirectional sources, i.e. $\Delta L_{W,\mathrm{dir,hor}} = \Delta L_{W,\mathrm{dir,vert}} = 0$ dB.

Fig. 3 shows the effect of the dipole-like $\Delta L_{W,\mathrm{dir,hor}}$ of CNOSSOS on sound exposure. For example, for a 160° track viewing angle CNOSSOS' $\Delta L_{W,\mathrm{dir,hor}}$ leads to a reduction in the L_{eq} by 2.5 dB. Whereas the vertical

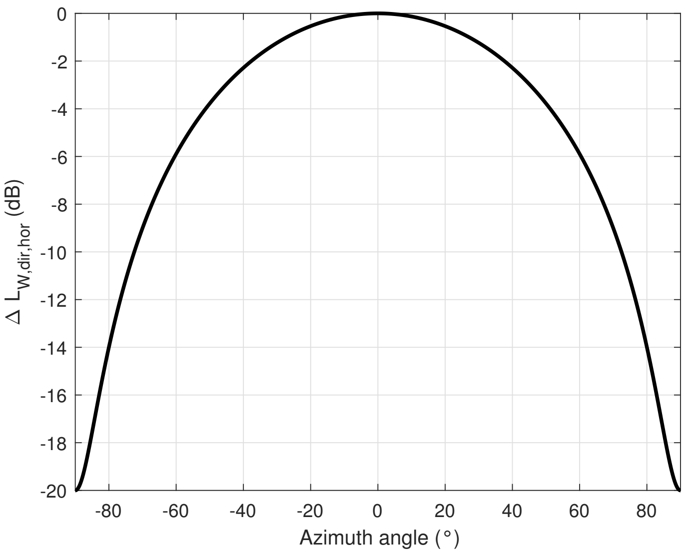


Figure 1: Horizontal directivity pattern of CNOSSOS for rolling noise (Azimuth 0° = perpendicular to the track).

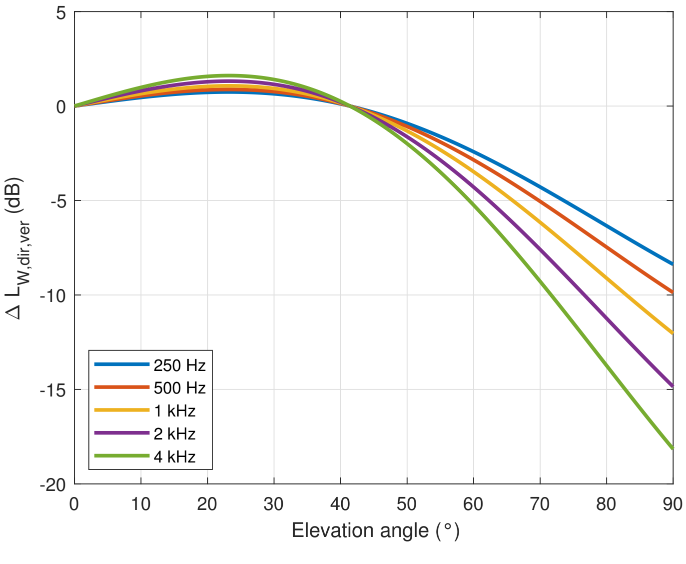


Figure 2: Vertical directivity pattern of CNOSSOS rolling noise source for selected 1/3 octave bands.

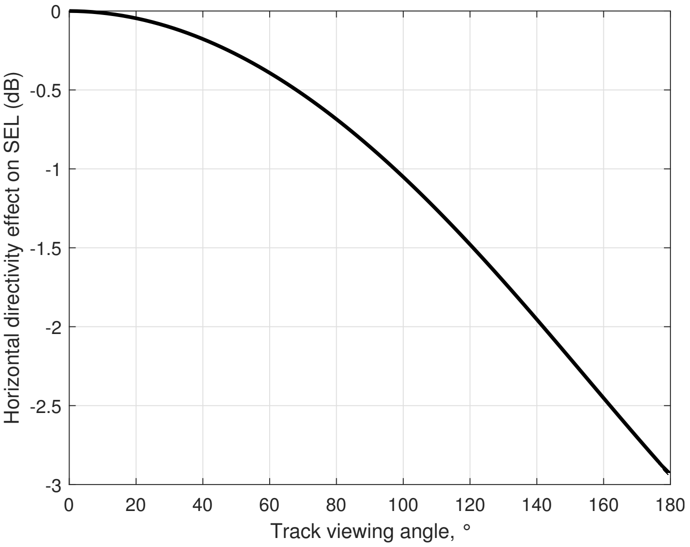


Figure 3: Effect of the dipole-like horizontal directivity on sound exposure as a function of the track viewing angle (180° = full view) considering propagation attenuation due to geometrical divergence.

directivity of CNOSSOS in the standard geometry for railway noise emission measurements (5° elevation) amounts to an amplification by 0.2–0.5 dB. In the standard geometry, the CNOSSOS directivity effect on rolling noise exposure is thus estimated to -2 dB.

If the source is behind a noise barrier, the representative source radiation occurs at a higher elevation angle. A barrier of 2 m height at 2.5 m to the track center results in a rolling noise elevation angle of 40°. According to Fig. 2 for this elevation the vertical directivity effect in CNOSSOS is 0 dB and thus emissions are 0.2–0.5 dB lower than for the standard conditions.

3.2.3 Rolling noise

In both models, rolling noise is calculated based on the combined effective roughness level $L_{R,\mathrm{tot}}$ in 1/3 octave wave-number bands by

$$L_{R,\mathrm{tot},m} = 10\ \log_{10}\left(10^{0.1L_{r,\mathrm{tr},m}} + 10^{0.1L_{r,\mathrm{veh},m}}\right) + A_{3,m} \tag{2}$$

with wave-number band indices m, the rail roughness level spectrum $L_{r,\mathrm{tr},m}$, the wheel roughness level spectrum $L_{r,\mathrm{veh},m}$, and the contact filter $A_{3,m}$. Both models provide numerical values for these parameters in tables. Both models provide multiple database entries for $L_{r,\mathrm{tr},m}$, entries for various wheel brake types for $L_{r,\mathrm{veh},m}$ (see comparisons in [9]) and similar entries for $A_{3,m}$. Although CNOSSOS mentions that rolling noise is mainly excited by the wavelength range from 5–500 mm, its database covers 0.8-1000 mm. sonRAIL covers a smaller wavelength range of 1–630 mm, which however still goes beyond the major wavelength bands. The considered wavelength range defines the limits of the resulting frequency and speed ranges. The sonRAIL model is only valid and applied for travelling speeds v between 50 and 200 km/h. Employing the wavelength-frequency conversion

$$f = \frac{v}{\lambda} \tag{3}$$

used in both models, the limitation in frequency of sonRAIL is found at the lower end, namely at 100 Hz. After the conversion into the frequency domain, both models apply spectral transfer functions to the combined effective roughness to obtain the sound power levels for separate contributions in the form

$$L_{W,\mathrm{tr},i} = L_{R,\mathrm{tot},i} + L_{H,\mathrm{tr},i} + 10\ \log_{10}\left(N_{\mathrm{ax}}\right) \tag{4}$$

$$L_{W,\mathrm{veh},i} = L_{R,\mathrm{tot},i} + L_{H,\mathrm{veh},i} + 10\ \log_{10}\left(N_{\mathrm{ax}}\right) \tag{5}$$

with the frequency band index i, transfer functions L_H for different physical components that radiate sound, and the number of axles per vehicle N_{ax}. Both models contain two transfer functions, i.e. one for the track representing the radiated sound from the rails and the sleepers (above denoted as 'tr'), and one for the vehicle representing primarily the radiated sound from the wheelset and the boogie (above denoted as 'veh').

CNOSSOS forsees an additional third transfer function for the superstructure of the vehicle. However, the CNOSSOS source database only contains data for the common two transfer functions.
The CNOSSOS model attributes the total rolling (and impact) noise to its lower source at 0.5 m above rail head. sonRAIL, inspired by the IMAGINE model [7], is somewhat more detailed and physically correct by attributing the contribution radiated by the track to its lowest source at 0 m and the contribution radiated by the vehicle to the source at 0.5 m.

3.2.4 Impact noise

Both models consider impact noise due to rail joints, crossings or switches. In both models this is accomplished by introducing an additional equivalent roughness wavelength spectrum $L_{r,\mathrm{impact},m}$ to the rolling noise calculation. $L_{r,\mathrm{impact},m}$ is energetically added to get a modified total roughness in the wavelength domain. However, between the two models the definitions of $L_{r,\mathrm{impact},m}$ and thus their application differ [9]. In CNOSSOS, $L_{r,\mathrm{impact},m}$ is added to the total effective roughness $L_{R,\mathrm{tot},m}$, as in IMAGINE [7]. In sonRAIL, impact noise only affects the contribution radiated by the track and $L_{r,\mathrm{impact},m}$ is added before applying the contact filter. Transformed impact roughness spectra of CNOSSOS and sonRAIL are compared in Fig. 11 of [9].

3.2.5 Traction noise

In both models traction noise is described as a sound power level $L_{W,i}$ in 1/3 octave bands per vehicle and distributed between the vertical source heights. CNOSSOS describes $L_{W,i}$ as a constant term per vehicle type, independent of the operating conditions. A more detailed description is made in sonRAIL where $L_{W,i}$ is a function of the travelling speed v and individually determined per vehicle type, frequency band and the four source heights 0.5, 2, 3 and 4 m.

3.2.6 Other sources

Both models further describe more specific sources and for instance consider

- elevated noise in curves,
- aerodynamic noise
- and noise radiated by bridges.

CNOSSOS considers curve squeal for curves with a radius below 500 m. sonRAIL namely neglects curve squeal but considers increased rolling noise in curve segments with a radius below 1000 m. Aerodynamic noise is in both models described by sound power levels with a logarithmic speed dependence in the form

$$L_{W,\mathrm{aero},i} = L_{W,\mathrm{aero},i}(v_0) + \alpha_{\mathrm{aero}} 10\ \log_{10}\left(\frac{v}{v_0}\right) \tag{6}$$

with a reference speed v_0. Bridge noise highly depends on the bridge type. In CNOSSOS, bridge noise is modeled by an artificial level increase in rolling noise, whereas in sonRAIL bridge noise is described independent of rolling noise by a separate sound power. In addition to the mentioned sources, sonRAIL describes the effects of tunnel openings, track ballast and wheel flats.
Since in most Swiss cases these specific sources are of minor importance, they are not considered in the following numerical comparisons.

4 Calculation results

In this section we present and compare numerical calculation results. Three types of calculations are performed which are denoted as:

- *sonRAIL*: sonRAIL method with sonRAIL default parameters
- *CNOSSOS/default*: CNOSSOS method with its default input parameters
- *CNOSSOS/CH*: CNOSSOS method with Swiss input data from sonRAIL

Comparisons between the models with their default settings are shown in Section 4.1 to give an overall impression of the methods and their corresponding input parameter databases. To further assess the conformity of the sonRAIL model with CNOSSOS, in Section 4.2 results by the CNOSSOS method using Swiss input data from the sonRAIL parameter database are compared to sonRAIL results.

Since sound power level is used in an ambiguous way in [4], instead an equivalent sound pressure level at a reference distance of 1 m to the source is used for the comparisons that also considers possible directivity effects by integration over a typical pass-by as derived in Section 3.2.2. The following numerical results are based on the standard emission measurement geometry with a vertical radiation angle of 5° for rolling and impact noise sources and a 160° track viewing angle, yielding a CNOSSOS directivity effect on rolling and impact noise exposure of -2 dB. Ground or ballast effects are not considered. All stated quantities denoted as emission levels are sound pressure levels as A-weighted third octave spectra or A-weighted total levels indicated by 'Tot'.

When deviating from the standard geometry, source directivity effects may lead to different apparent emissions. Objects in the propagation path such as buildings or a noise barrier influence the relevant emission angle range, as for example buildings leading to a reduced track viewing angle or a noise barrier that increases the relevant elevation angle of rolling and impact sources. As compared to the made assumptions, according to Figure 3, a reduction in the track viewing angle to 120° or 90° will result in 1 or 1.6 dB lower emissions for sonRAIL than for CNOSSOS, respectively. According to Section 3.2.2 a tyical noise barrier will lead to 0.2–0.5 dB higher apparent rolling noise emissions for sonRAIL as compared to CNOSSOS. However, in this case also the different approaches to consider ground, ballast and shielding effects between the models should be considered.

4.1 Comparisons with default settings (CNOSSOS/default vs sonRAIL)

In this section, the most relevant source types are separately compared, namely

- rolling noise,
- impact noise and
- traction noise.

For these sources, cases that are relevant with respect to noise exposure and that can be handled with both models were selected.

4.1.1 Rolling noise

Comparisons for rolling noise are performed for different vehicles, superstructures and speeds v. The standard wheel diameter of 920 mm, an axle load of 50 kN and 4 axles are chosen. The comparisons are made for different wheel and rail roughness conditions and the three track types

- concrete monoblock sleepers (medium pad stiffness),
- concrete biblock sleepers (medium pad stiffness),
- wooden sleepers.

A total of 6 freight wagon types and operating conditions is considered by running simulations for the two brake types cast iron brake blocks and composite brake blocks (K-blocks), and the three speeds v = 50, 70 and 90 km/h. Also a total of 6 passenger wagon types and operating conditions is considered by running simulations for the two brake types K-brake blocks and disc brakes, and the three speeds v = 60, 90 and 130 km/h. This amounts to 36 comparison cases for rolling noise.

Figure 4 shows a compilation of the default rail roughness level spectra of the two models. sonRAIL differentiates between three basic rail roughness conditions, i.e. smooth, average and bad. Therefore for rolling noise a total of 108 cases are calculated with the sonRAIL default parameters. CNOSSOS offers the ISO curve and an average rail roughness condition which is used for the calculations.

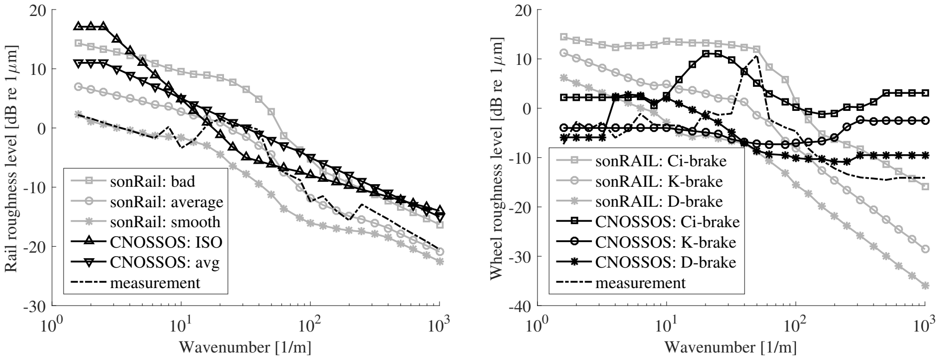


Figure 4: Rail (left) and wheel (right) roughness default parameters of CNOSSOS and sonRAIL (taken from [9]).

Figure 5 shows rolling noise of freight wagons on a track with concrete monoblock sleepers and rail pads with medium stiffness. Figures 6 and 7 show the same situations but for concrete biblock and for wooden sleepers, respectively. The following Figures 8, 9 and 10 show simulation results for passenger wagons, i.e. with smoother wheel surfaces and higher speeds.

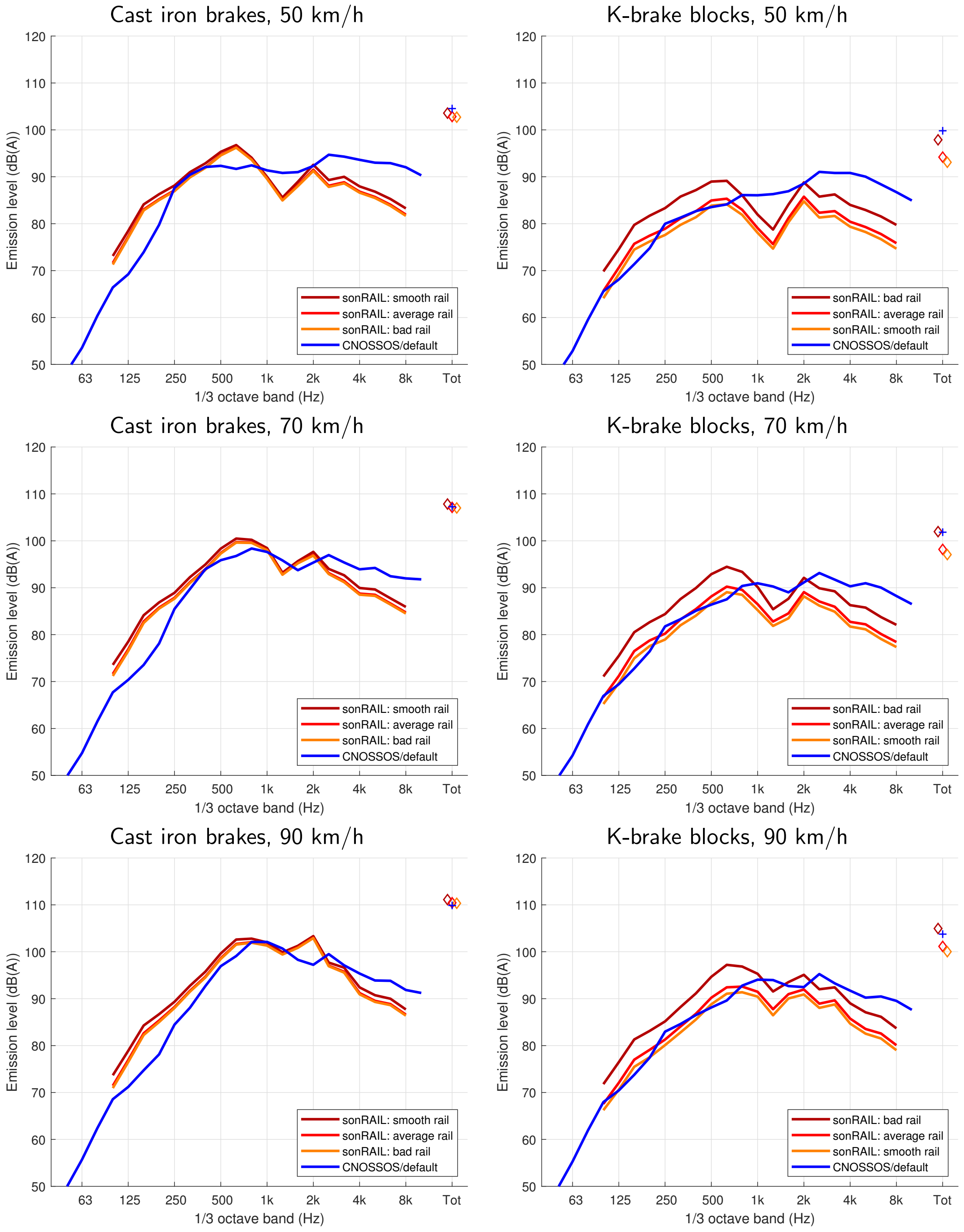


Figure 5: Rolling noise calculation comparisons with default model parameters of freight wagons with cast iron (left) and K-brake blocks (right) at speeds $v = 50$, 70 and 90 km/h on a track with concrete **monoblock** sleepers and medium pad stiffness.

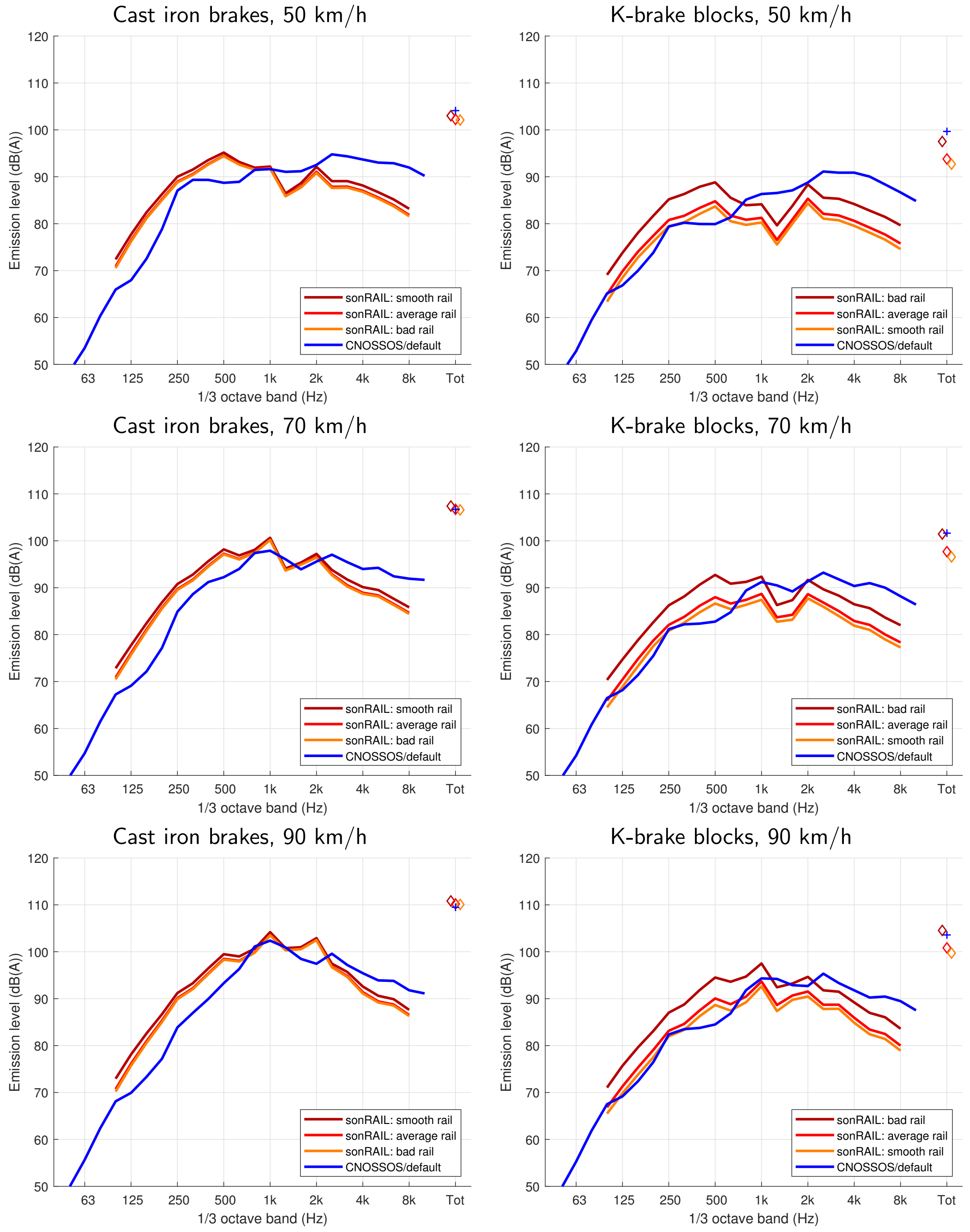


Figure 6: Rolling noise calculation comparisons with default model parameters of freight wagons with cast iron (left) and K-brake blocks (right) at speeds v = 50, 70 and 90 km/h on a track with concrete **biblock** sleepers and medium pad stiffness.

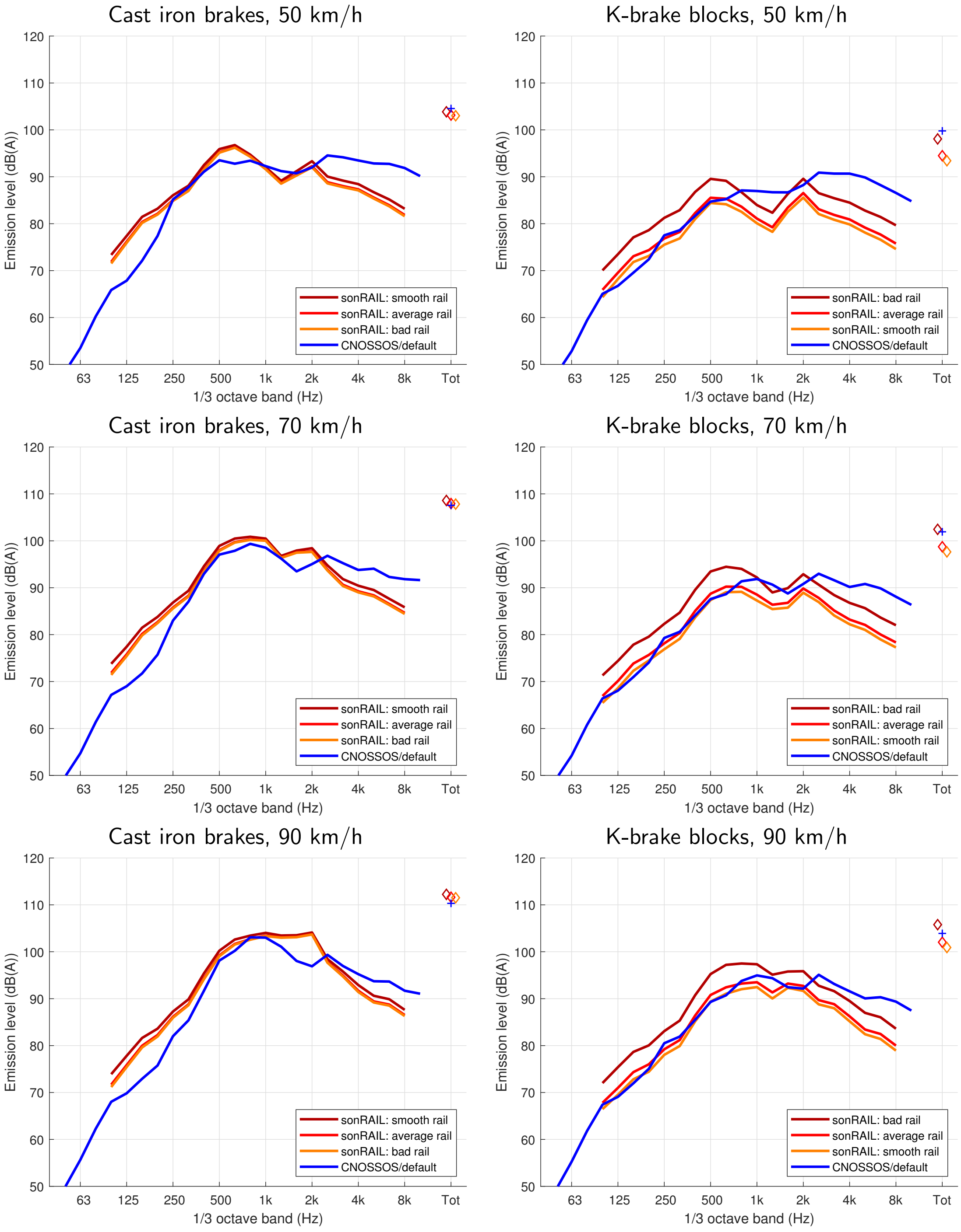


Figure 7: Rolling noise calculation comparisons with default model parameters of freight wagons with cast iron (left) and K-brake blocks (right) at speeds v = 50, 70 and 90 km/h on a track with **wooden** sleepers.

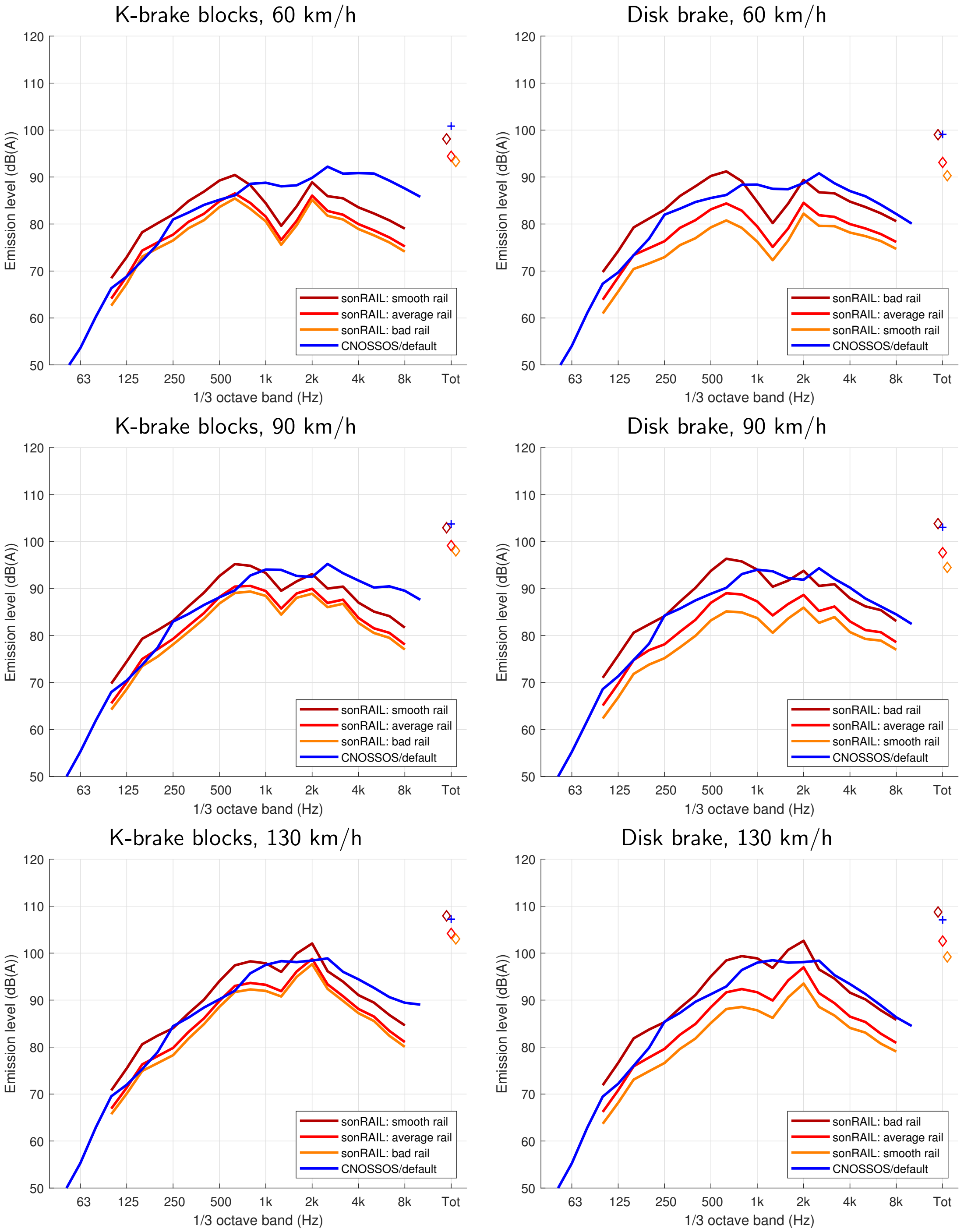
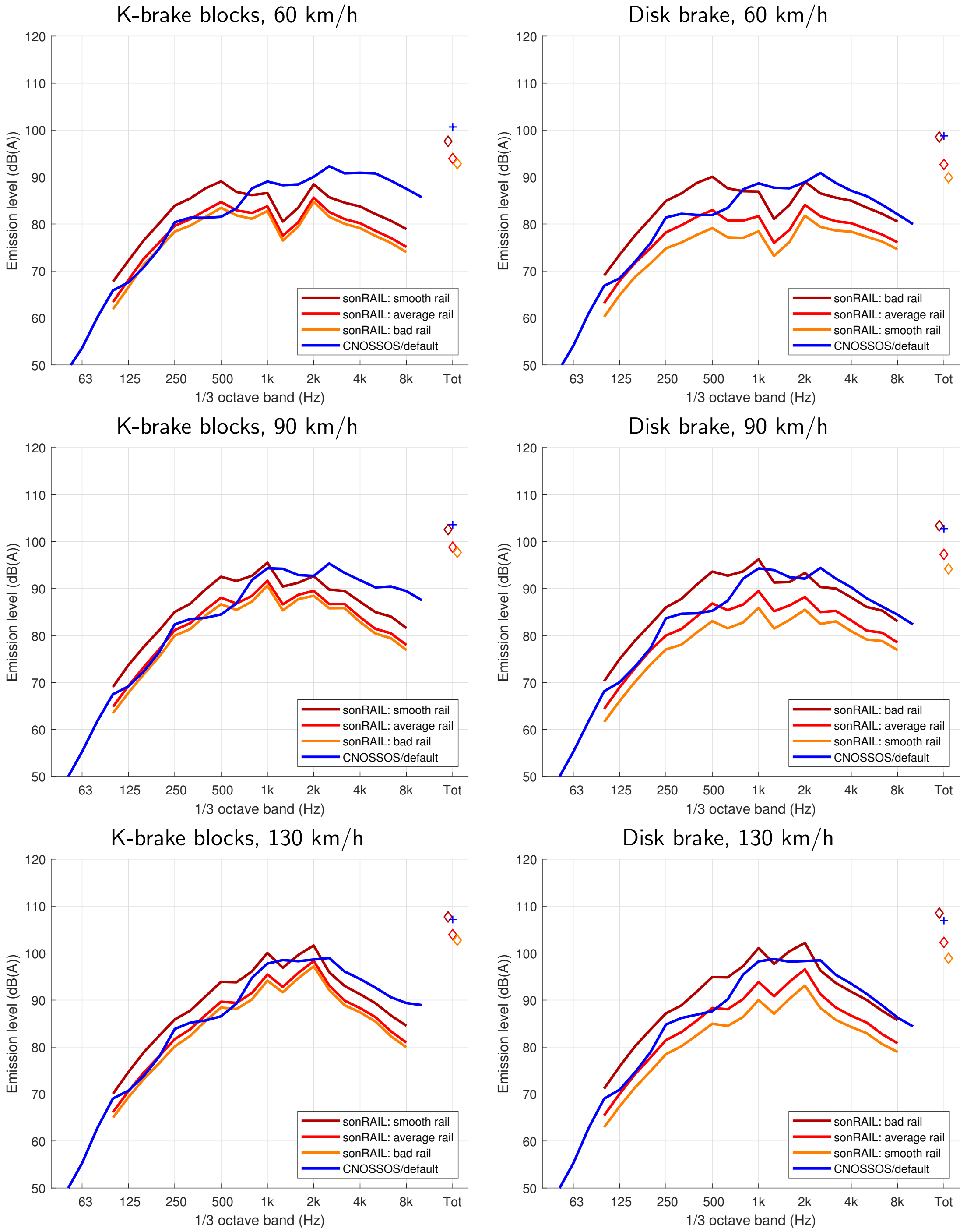


Figure 8: Rolling noise calculation comparisons with default model parameters of passenger wagons with K-brake blocks (left) and Disk brake (right) at speeds v = 60, 90 and 130 km/h on a track with concrete **monoblock** sleepers and medium pad stiffness.


K-brake blocks, 60 km/h

Disk brake, 60 km/h

K-brake blocks, 90 km/h

Disk brake, 90 km/h

K-brake blocks, 130 km/h

Disk brake, 130 km/h

Figure 9: Rolling noise calculation comparisons with default model parameters of passenger wagons with K-brake blocks (left) and Disk brake (right) at speeds v = 60, 90 and 130 km/h on a track with concrete **biblock** sleepers and medium pad stiffness.

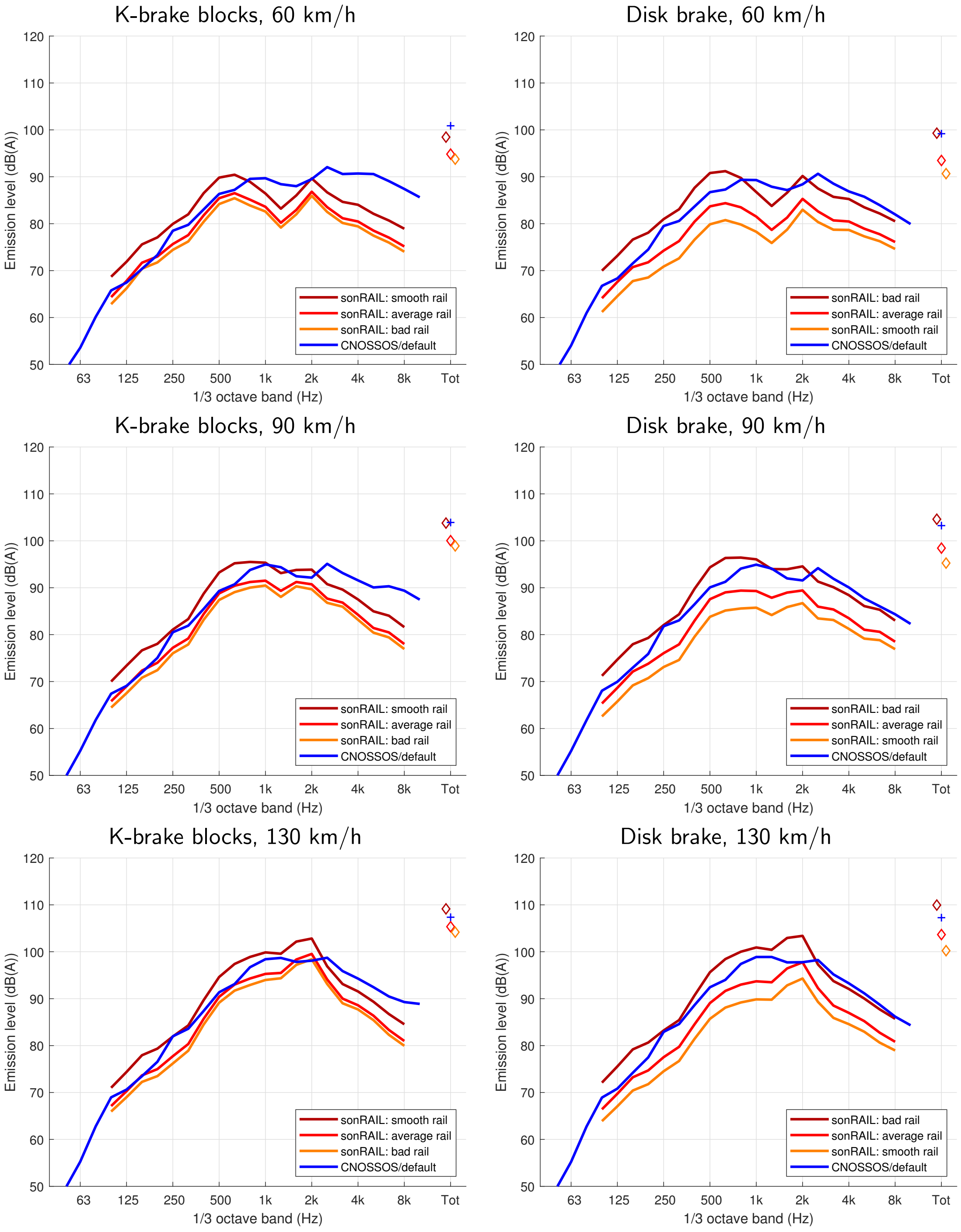
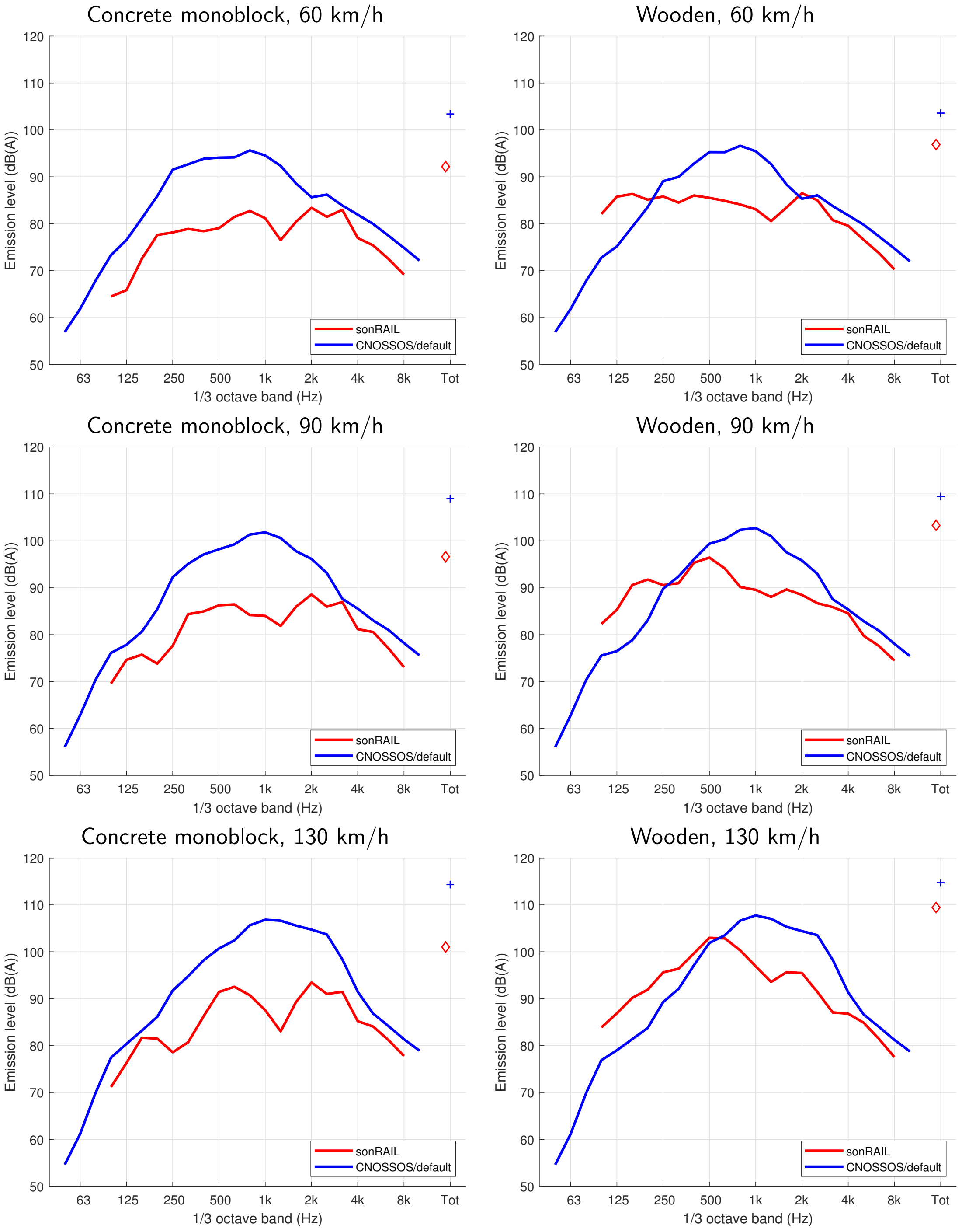


Figure 10: Rolling noise calculation comparisons with default model parameters of passenger wagons with K-brake blocks (left) and Disk brake (right) at speeds v = 60, 90 and 130 km/h on a track with **wooden** sleepers.

Generally a good agreement between the two models were found for rolling noise. This was expected since both models are based on the same principles and formulas. Interestingly, the emissions found with the CNOSSOS *average* rail condition correspond best with the sonRAIL input parameter set for *bad* rail condition, i.e. high rail roughness levels. This is supported by the fact that for wavelengths below 1 cm the corresponding roughness curves are closest according to Figure 4. sonRAIL predicts mostly lower rolling noise emissions above 2 kHz than CNOSSOS with its default parameters. This can be partly attributed to the lower wheel roughness levels for all three brake types at high wavenumbers (see Figure 4).



Concrete monoblock, 60 km/h

Wooden, 60 km/h

Concrete monoblock, 90 km/h

Wooden, 90 km/h

Concrete monoblock, 130 km/h

Wooden, 130 km/h

Figure 11: Impact noise calculation comparisons with default model parameters at speeds v = 60, 90 and 130 km/h on track with concrete monoblock sleepers (left) and wooden sleepers (right).

4.1.2 Impact noise

Impact noise depends on the vehicle type, track type and speed. Comparisons are made for a single axle, the standard wheel diameter of 920 mm, an axle load of 50 kN, the three speeds v = 60, 90 and 130 km/h, and the two track types, i.e. concrete monoblock and wooden sleepers. This makes a total of 6 cases.

Figure 11 shows impact noise emission levels for different speeds and two superstructure types. Although the general spectral shapes between the models are similar, the emission levels of sonRAIL are generally lower than with CNOSSOS. The difference can amount to more than 10 dB and be partly explained by the higher equivalent impact roughness used in CNOSSOS (see Figure 11 in [9]).

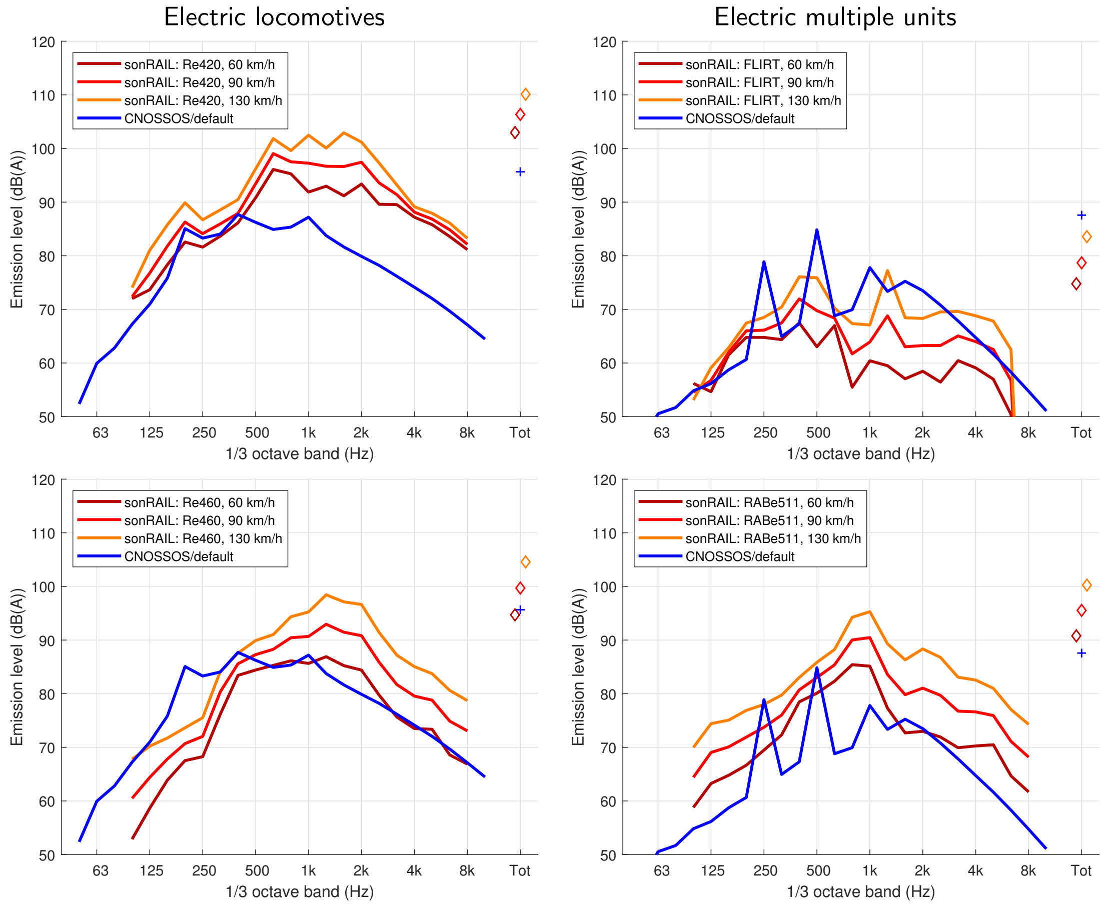


Figure 12: Traction noise calculation comparisons with default model parameters for different electric locomotives.

4.1.3 Traction noise

There are no Diesel locomotives in regular operation in Switzerland and thus no source data available in the sonRAIL source database. The traction noise comparison is thus restricted to electric locomotives. CNOSSOS/default only specifies sound power levels for two electric locomotives. In Figure 12 this data is compared to emission levels from sonRAIL of different electric locomotives and electric multiple units at different speeds $v = 60$, 90 and 130 km/h.

The spectra exhibit a similar pattern with a broad maximum in the middle frequency range. Depending on the vehicle type and speed however large differences of more than 10 dB between the sonRAIL and CNOSSOS default traction emissions occur. The exemplary sonRAIL data already demonstrates a 10 dB difference between vehicles of the same class at the same speed, e.g. the two electric multiple units FLIRT and RABe511, as well as between different relevant speeds for the same vehicle, e.g. the Re460, RABe511 and FLIRT. This indicates the necessity to differentiate between various vehicle types and their operational conditions for traction noise emissions and thus limits the possibility for conclusive traction noise comparisons between the two models since CNOSSOS does not consider operational conditions.

4.2 Comparisons with Swiss input parameters (CNOSSOS/CH vs sonRAIL)

4.2.1 Rolling noise

For rolling noise the same cases with respect to vehicles, their speed and the superstructure type as in Section 4.1 are considered in the following comparisons. However, only the *average* rail roughness condition from sonRAIL is used since for the other roughness data very similar results are expected. This amounts to a total of 36 comparison cases.

Figure 13 shows rolling noise of freight wagons on a track with concrete monoblock sleepers and rail pads with medium stiffness. Figures 14 and 15 show the same situations but for concrete biblock and for wooden sleepers, respectively. The following Figures 16, 17 and 18 show simulation results for passenger wagons, i.e. with smoother wheel surfaces and higher speeds.

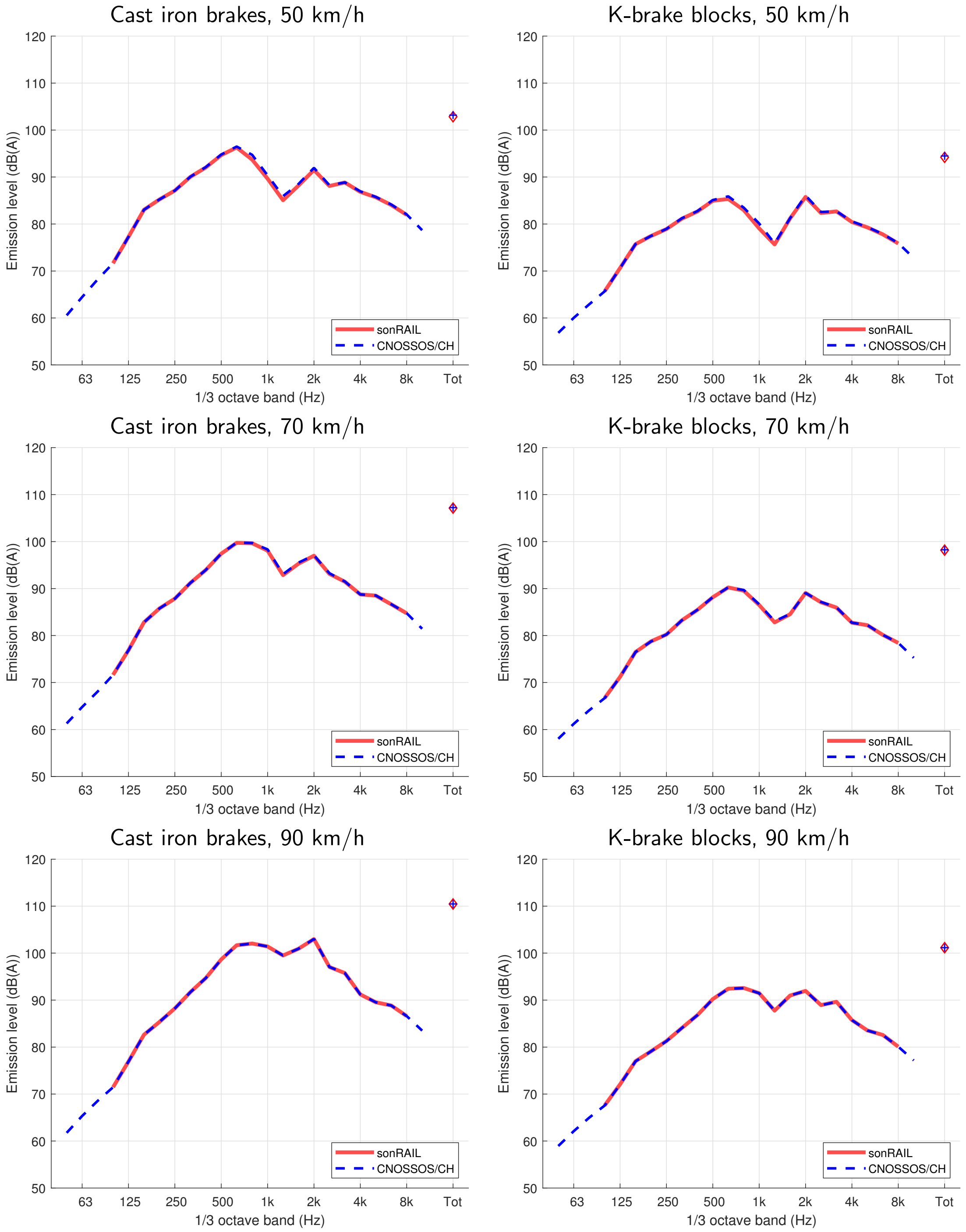
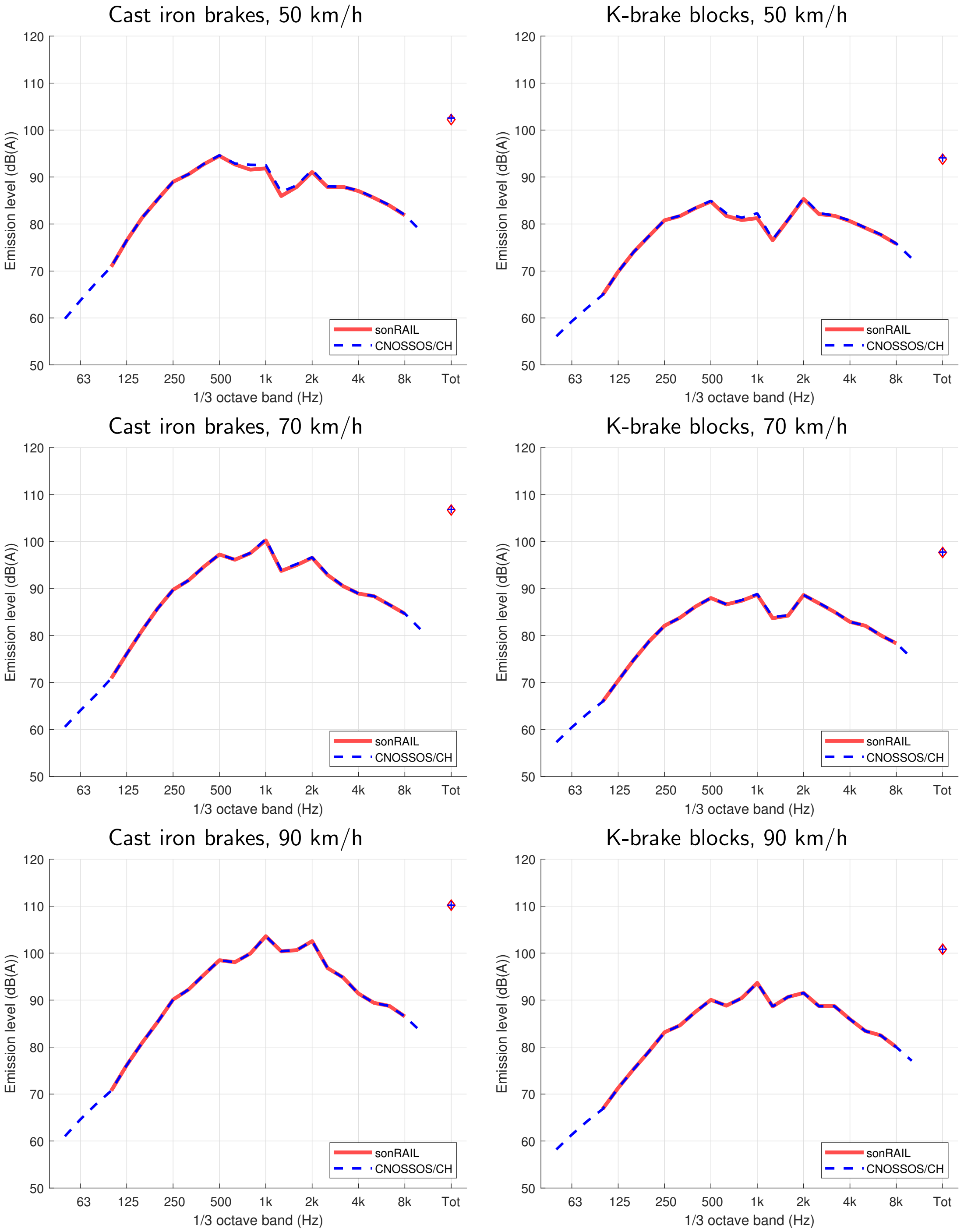


Figure 13: Rolling noise calculation comparisons with Swiss model parameters of freight wagons with cast iron (left) and K-brake blocks (right) at speeds $v = 50$, 70 and 90 km/h on a track with concrete **monoblock** sleepers and medium pad stiffness.



Cast iron brakes, 50 km/h

K-brake blocks, 50 km/h

Cast iron brakes, 70 km/h

K-brake blocks, 70 km/h

Cast iron brakes, 90 km/h

K-brake blocks, 90 km/h

Figure 14: Rolling noise calculation comparisons with Swiss model parameters of freight wagons with cast iron (left) and K-brake blocks (right) at speeds $v = 50$, 70 and 90 km/h on a track with concrete **biblock** sleepers and medium pad stiffness.

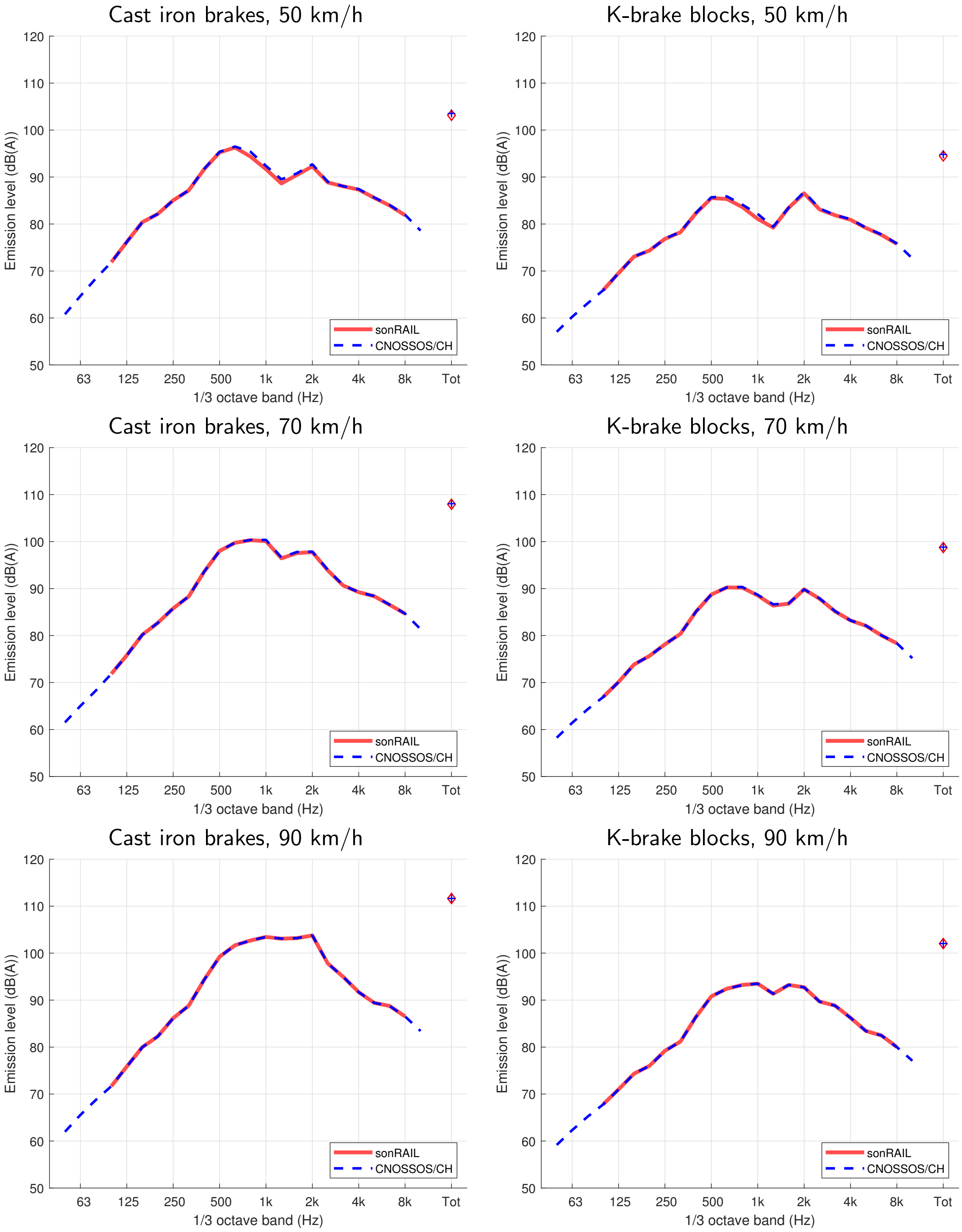


Figure 15: Rolling noise calculation comparisons with Swiss model parameters of freight wagons with cast iron (left) and K-brake blocks (right) at speeds v = 50, 70 and 90 km/h on a track with **wooden** sleepers.

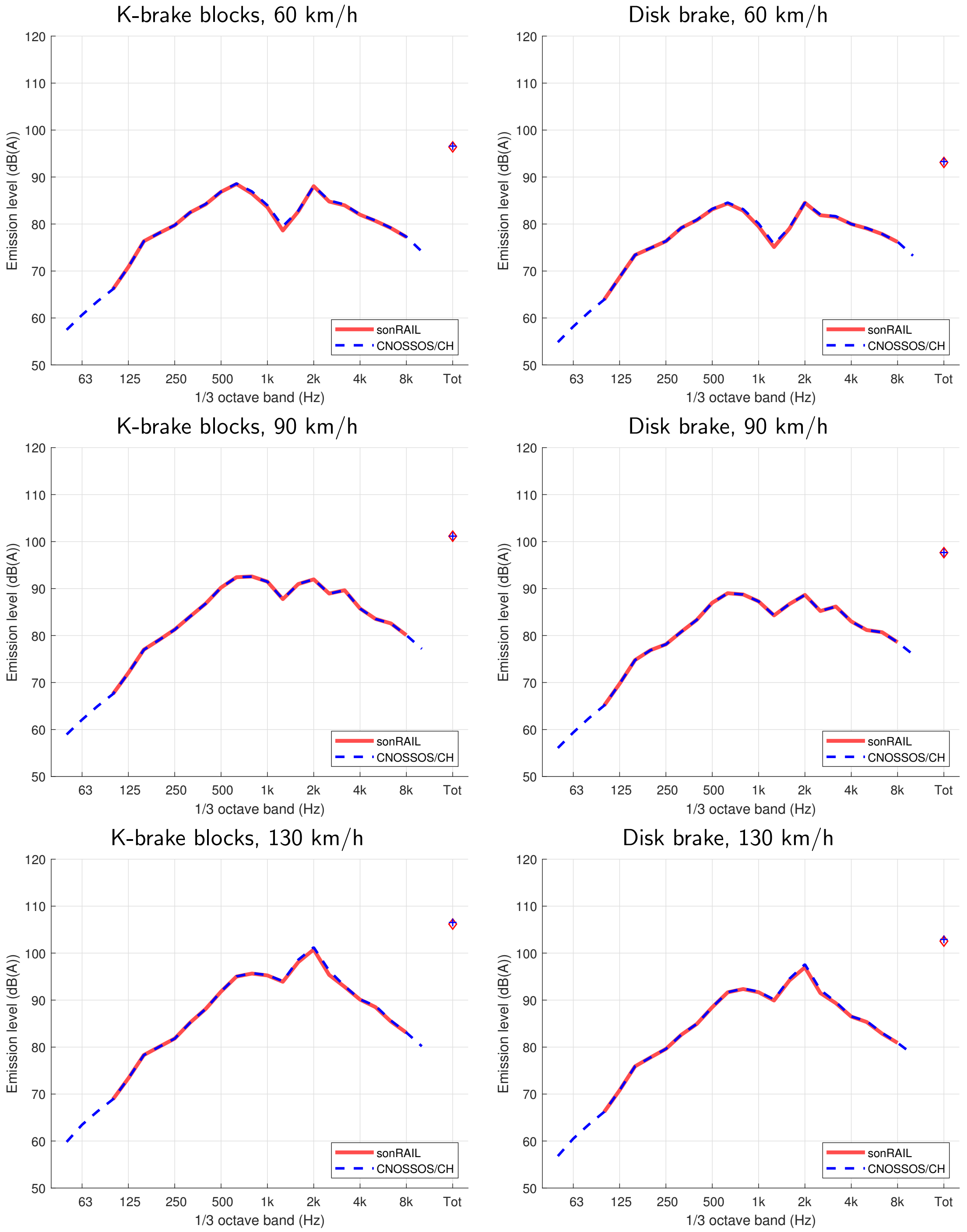


Figure 16: Rolling noise calculation comparisons with Swiss model parameters of passenger wagons with K-brake blocks (left) and Disk brake (right) at speeds v = 60, 90 and 130 km/h on a track with concrete **monoblock** sleepers and medium pad stiffness.

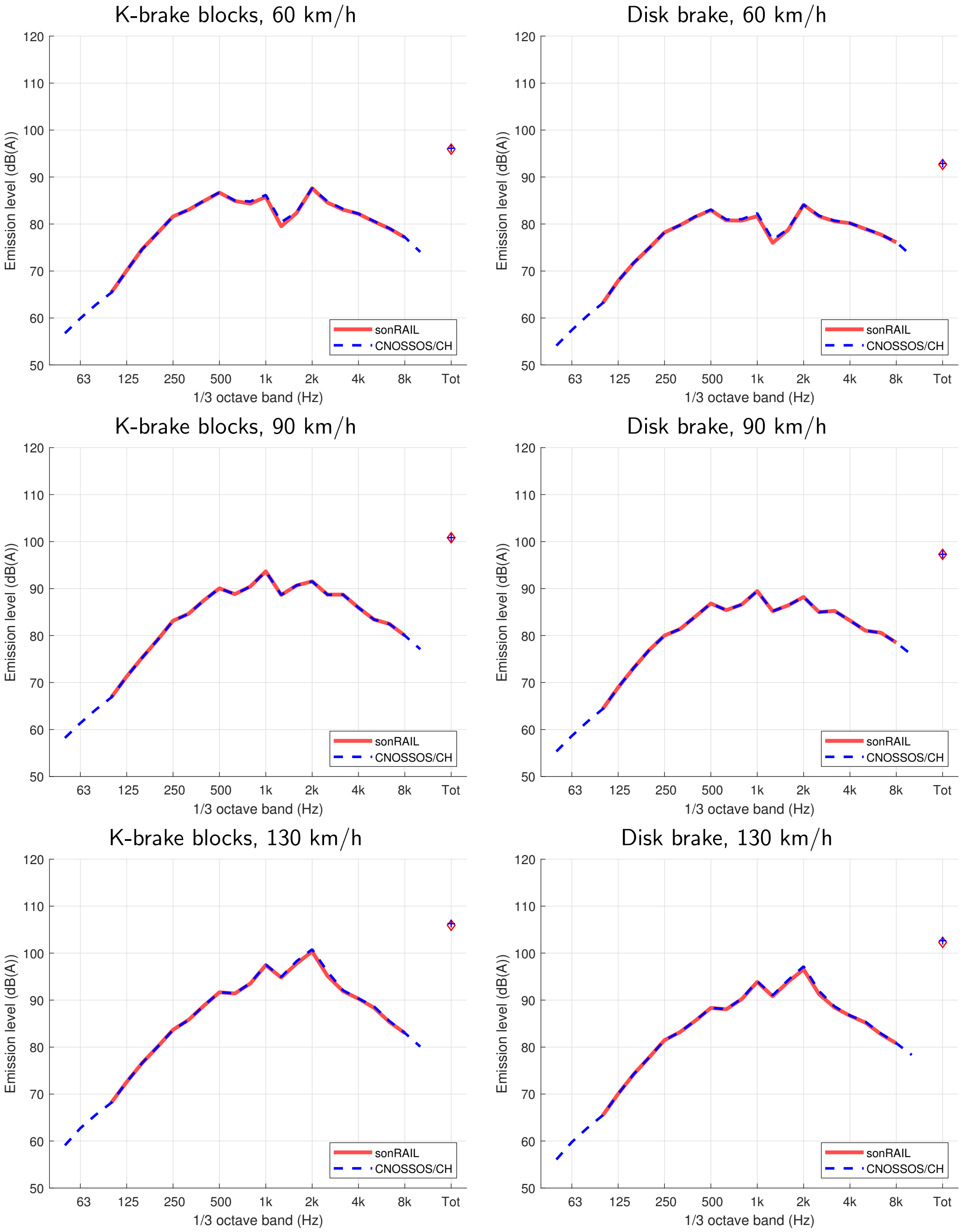


Figure 17: Rolling noise calculation comparisons with Swiss model parameters of passenger wagons with K-brake blocks (left) and Disk brake (right) at speeds $v = 60$, 90 and 130 km/h on a track with concrete **biblock** sleepers and medium pad stiffness.

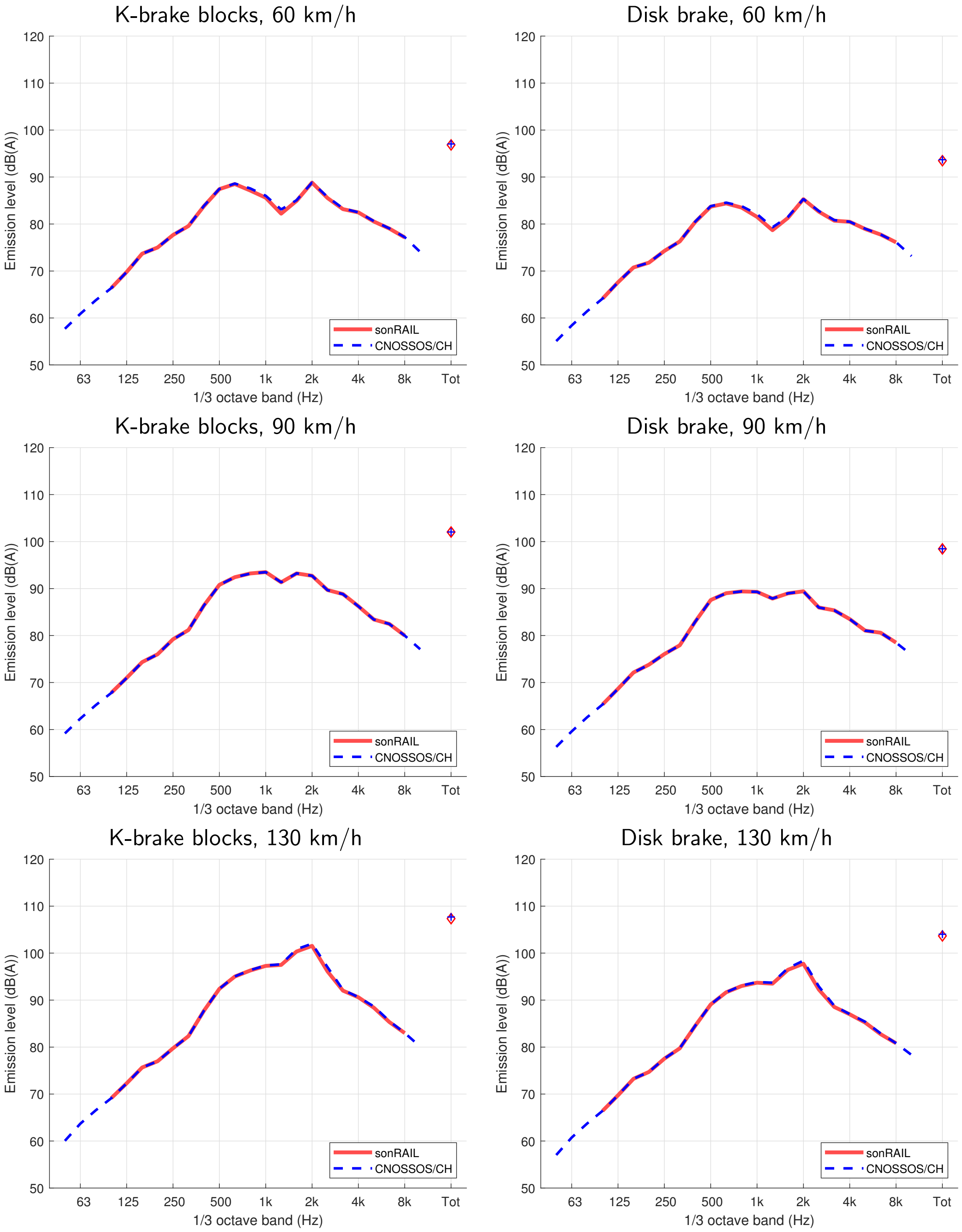


Figure 18: Rolling noise calculation comparisons with Swiss model parameters of passenger wagons with K-brake blocks (left) and Disk brake (right) at speeds v = 60, 90 and 130 km/h on a track with **wooden** sleepers.

An excellent agreement between the two models was found for rolling noise when the Swiss input parameters are taken for both models. This was expected since both models are based on nearly the same formulas and differ only in some minor aspects regarding data range and an interpolation algorithm. The limitation in frequency range in the sonRAIL model for example seems justified since the influence of the missing bands is negligible for the total A-weighted emission level. For the lowest three CNOSSOS bands the attenuation due to the A-weighting is high (30, 26 and 23 dB) and at 10 kHz the noise emission level per se is low.

4.2.2 Impact noise

For impact noise the same cases with respect to vehicles, their speed and the superstructure type as in Section 4.1 are considered in the following comparisons. Figure 19 shows impact noise emission levels for

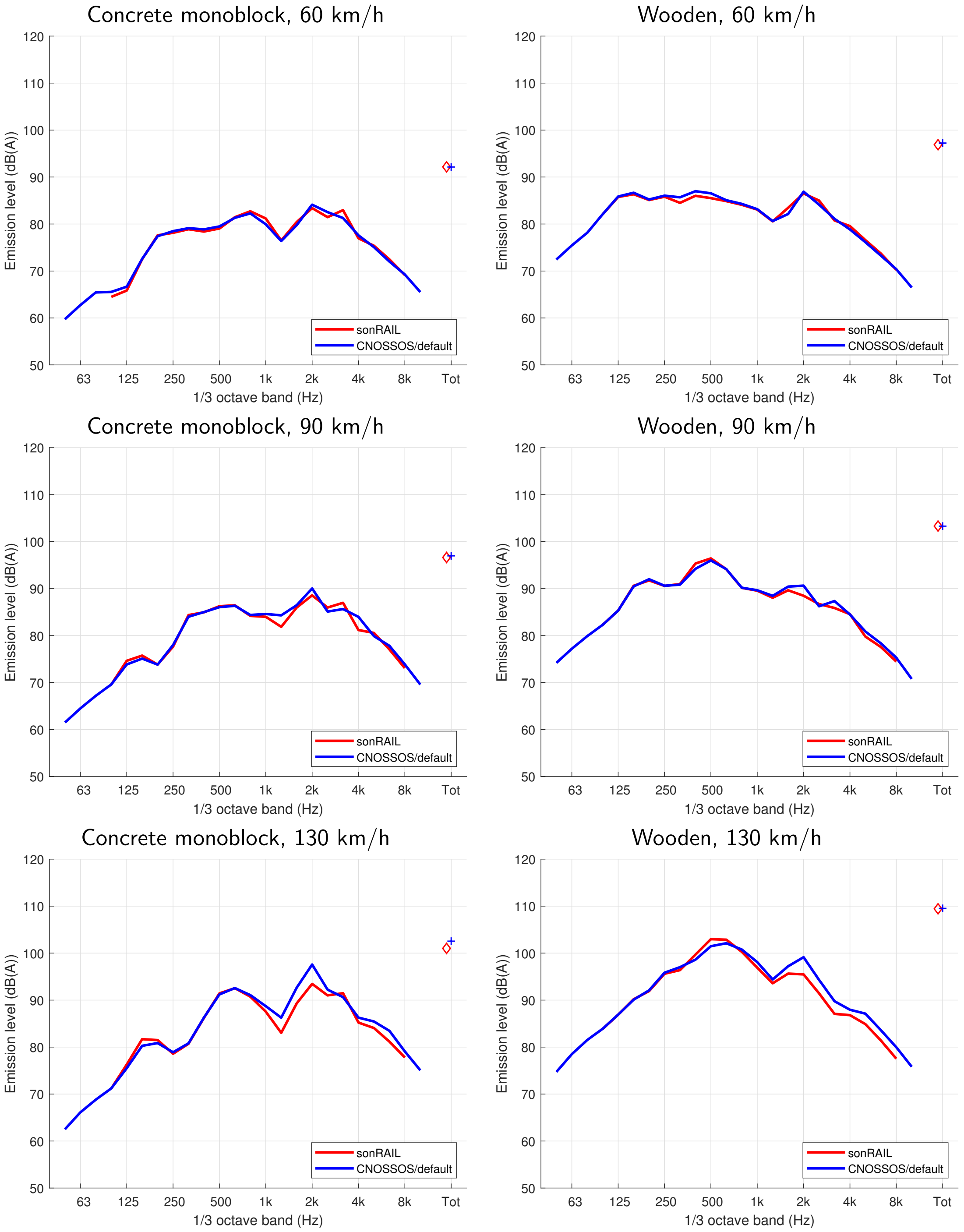


Figure 19: Impact noise calculation comparisons with Swiss model parameters at speeds v = 60, 90 and 130 km/h on track with concrete monoblock sleepers (left) and wooden sleepers (right).

three speeds and two superstructure types.
Since for the impact noise the calculation scheme and the definition of the input parameters (equivalent roughness spectra) differ between the models, Swiss input parameters for CNOSSOS have to be derived with some transformations, e.g. correction for the contact filter. Figure 19 shows that in contrast to the large differences with the default inputs in Figure 11 with appropriate equivalent roughness spectra a good agreement between sonRAIL and CNOSSOS is found.

4.2.3 Traction noise

Section 4.1 has shown that sonRAIL is more accurate with respect to traction noise and other secondary sources because in contrast to CNOSSOS it justifiably considers various vehicle types per class and the vehicle speed. Therefore a comparisons of sonRAIL and CNOSSOS/CH is not revealing and omitted.

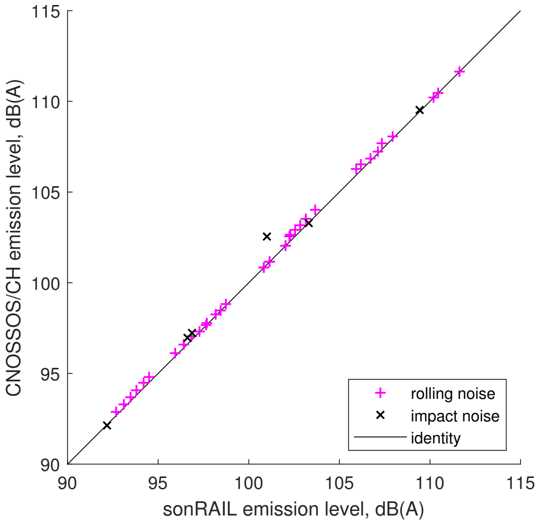


Figure 20: Comparison of A-weighted emission levels from sonRAIL and from CNOSSOS with Swiss input data.

4.2.4 Overall evaluation

For an overall evaluation, in Figure 20 the previously presented rolling and impact noise cases are compiled and their A-weighted emission levels are compared in a scatter plot. Over the whole considered emission level range an excellent agreement can be observed.

For rolling noise, the mean of the differences between CNOSSOS/CH and sonRAIL was found at −0.2 dB and a standard deviation of the differences of 0.1 dB. For impact noise, slightly higher differences occur with the mean of the differences at −0.4 dB and the standard deviation of the differences of 0.6 dB. The mean deviations between sonRAIL and CNOSSOS/CH for rolling and impact noise are thus below 0.5 dB on average.

5 Conclusions

The sonRAIL railway noise emission model is very similar to the CNOSSOS-EU model for railway noise of moving trains. Several differences between the models were identified in the detailed model descriptions which however only minimally affected the overall A-weighted emission levels in the standard geometry. In shielded geometries differences in source directivity may lead to 1.5 dB lower to 0.5 dB higher rolling and impact noise emissions for sonRAIL as compared to CNOSSOS-EU, neglecting possible compensating propagation model differences. For the most relevant noise source, i.e. rolling noise, the calculations are nearly coincident. Apart from that, sonRAIL is more detailed in the description of secondary sources like traction noise, whereas for impact noise CNOSSOS is closer to the physical mechanisms than sonRAIL. With the model's default parameter settings considerable differences of multiple dB between the models were found. Using Swiss input data, average differences between emission calculations with the sonRAIL model and the CNOSSOS-EU model for rolling and impact noise are below 1 dB. This leads to the conclusion that sonRAIL has a high level of conformity with CNOSSOS-EU.

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