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Report

Test Cases for Railway Noise Nord2000

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Contents

Forord

Miljøstyrelsen bad i 2004 DELTA om at udarbejde et sæt af beregningsforudsætninger og dertil hørende beregningsresultater, som kan benyttes til test af computerprogrammer, der beregner vejtrafikstøj efter den nye nordiske beregningsmetode Nord2000. Testeksemplerne blev offentliggjort i Miljøstyrelsens "Environmental Project 1022/2005". Siden da er Nord2000-metoden i perioden 2005-06 blevet revideret i et fælles nordisk projekt, hvorved der blev ændret på både beregning af lydudbredelse og på kildemodellen for vejstøj. Siden revisionen af metoden er der fundet tilfælde, hvor det har været nødvendigt at forbedre Nord2000-metodens principper og algoritmer, ligesom der er fundet mindre fejl i den software, der har været brugt til at beregne testeksemplerne med. Testeksemplerne bliver derfor løbende revideret, så de er i overensstemmelse med den gældende udgave af Nord2000-metoden.

I 2011 bad Miljøstyrelsen for første gang DELTA om at udarbejde et sæt testeksempler for støj fra jernbaner. På samme måde som for testeksemplerne for vejtrafik har der efterfølgende været behov for at opdatere disse efter revision af Nord2000-metoden. Hovedformålet med testeksemplerne i denne rapport er at teste implementeringen af kildedata for de togtyper, der er til rådighed i beregningsmetoden. Da støj fra jernbaner oftest beregnes med samme software som støj fra veje, er det ikke fundet strengt nødvendigt at udarbejde testeksempler med udbredelseseffekter ud over fladt, græsdækket terræn.

For hvert beregningspunkt er det angivet, inden for hvilke intervaller beregningsresultaterne skal befinde sig, for at den testede software kan siges at regne korrekt i henhold til Nord2000.

Fra 2014 har Miljøstyrelsen besluttet, at testeksemplerne udgives i regi af Miljøstyrelsens Referencelaboratorium for Støjmålinger og således vil være at finde på denne hjemmeside www.referencelaboratoriet.dk.

Målgruppen for rapporten er konsulenter og producenter af beregningsprogrammer.

Foreword

The Danish Environmental Protection Agency has in 2004 asked DELTA to develop test examples, which are a set of presumptions together with corresponding computation results, suitable for verifying that computer programs indeed do perform in conformity with the new Nordic prediction method for road traffic noise, Nord2000. The test examples were published in "Environmental Project 1022/2005". Since then the prediction method has been revised during 2005-06 in a joint Nordic project, where both the propagation calculations and the source model for road traffic noise were adjusted. Since the revision of the method cases has been found where it has been necessary adjust the principles and algorithms of the Nord2000-method and furthermore, minor errors have been found in the software used to calculate the test examples. As a consequence, the test examples will currently be revised to be in accordance with the present version of Nord2000.

In 2011 the Danish Environmental Protection Agency asked DELTA for the first time to develop test examples for railway noise. Since the development it has been necessary to revise the test examples to be in accordance with the present version of Nord2000. The main purpose of the test examples in the present report has been to test the implementation of railway source data for available Danish train types. As noise from railway and road traffic very often are calculated using the same software it has not been found necessary to test for the effect of sound propagation except for flat grass-covered ground.

Intervals have been specified that computation results shall fall within in order for the software to be declared as in conformity with Nord2000.

As of 2014, the Danish Environmental Protection Agency has decided that the test examples are to be published under the auspices of the Reference Laboratory and thus will be available on this website www.referencelaboratoriet.dk.

The target group for the present report is consultants and developers or distributors of software for railway traffic noise prediction.

Sammenfatning og konklusioner

Denne rapport indeholder et antal testtilfælde for beregning af støj fra jernbaner med Nord2000.

Den første gruppe af testtilfælde omfatter for alle danske togkategorier beregninger med udbredelse over fladt terræn fra et jernbanespor med konstant lydeffekt langs sporet. Det primære formål med denne gruppe af testtilfælde er at kontrollere, om et computerprogram beregner i overensstemmelse med kildemodellerne for hver togtype. Beregninger er udført dels af årsmiddelværdien af støjbelastningen L_{den} og dels af maksimalværdien L_{pAmaxS} med tidsvægtning Slow. Resultaterne omfatter både A-vægtede støjniveauer og støjniveauer i 1/3-oktavbånd.

Den anden gruppe af testtilfælde omfatter beregninger med udbredelse over fladt terræn fra et jernbanespor med en forhøjet lydeffekt langs en del af sporet. Beregningerne omfatter 8 tilfælde med maksimalværdien L_{pAmaxS} og 1 tilfælde med årsmiddelværdien af støjbelastningen L_{den}.

Resultaterne er samlet i to Excelregneark.

Summary and Conclusions

The present report contains several test cases for calculation of noise from railways using Nord2000.

The first group of test cases includes for all Danish train categories, calculations of propagation over flat terrain from a railway line with constant sound power level along the track. The main purpose of the cases is to test that the software has been made in agreement with the Nord2000 source models for each train type. Test results have been made for the yearly average of the noise exposure L_{den} and for the maximum noise level L_{pAmaxS} with time weighting Slow. The test results include overall A-weighted sound pressure levels as well as one-third octave band levels.

The second group of test cases includes calculations of propagation over flat terrain from a railway line having an increased sound power level along a part of the track. The calculations comprise eight cases of the maximum noise levels L_{pAmaxS} and one case of the yearly average of the noise exposure L_{den}.

The test results are available in two Excel spreadsheets.

1. Introduction

The present report contains a number of test cases for which calculations have been carried out by the Nordic railway noise calculation method Nord2000. The model is described in Refs. [1], [3], [4], [5], and [8] ([5] and [8] contain a complete description of the propagation model including the latest changes). Source data for Danish trains are given in Ref. [2] (the values shown in [1] are not correct!). In case of tracks with change in the sound power level in a part of the track, the source model in Ref. [1] has been revised as described in [7].

Calculations for a constant sound power level along the rail track have been carried out for all available source data and two propagation distances. For each case the yearly average of the noise level has been calculated as well as the maximum noise level corresponding to time weighting Slow.

Supplementary, in the 2018 update of the test cases, calculations of the maximum sound pressure levels for cases which include a change in the sound power level has been added for one train type.

2. Test Case Calculation Input

Railway tracks with a constant sound power level along the track

Calculations have been carried out for the eight sets of train source data shown in Table 1. The table also shows the train speed that has been used in the calculations. The source data is taken from Ref. [2]. For the train type "Øresundstog", the data of Table 6 (marked reduced data) in Ref. [2] has been used and for the train type "Metro", the data of Table 7 (marked all data) in Ref. [2] has been used.

No.	Train type	Speed (km/h)
1	A & D: Passenger trains IC3 or IR4	120
2	Øresundstog	120
3	X2000	120
4	B, C, H & I: Passenger and goods train with ME, MZ or EA locomotives	120
5	E: Diesels train sets (MR), Y-trains, IC2-trains, RegioSprinter, Desiro	120
6	F2 & F3: S-trains, 2^{nd} and 3^{rd} generation	80
7	F4: S-trains, 4^{th} generation	80
8	Metro	80

Tabel 1
Source data of 8 train groups.

In calculations of the yearly average of the noise exposure L_{den} the total length of the trains per day divided on the time-of-day periods are shown in Table 2.

Time-of-day period	Total length of train per day (m)
Day	11000
Evening	3000
Night	3000

Tabel 2
Traffic information.

The ground surface between the railway track and the receiver is flat and covered with grass and the rail bed has the same height as the ground. The height of the rail above the rail bed is 0.2 m. The rail bed and the ground surface are assumed to have surface properties corresponding to Nord2000 impedance class D (flow resistivity of 200,000 Nsm^{-4}). Calculations are performed for a receiver 1.5 m above the ground surface and 10 and 100 m from the nearest rail.

The source line at the nearest rail has been divided into 179 source points placed with constant angle seen from the receiver. The angle resolution is 1°, and consequently the source points cover horizontal immission angles between ±89°.

The method for calculating the yearly average of L_{den} is described in [6]. The meteorological statistics for nine meteo-classes to be used in the calculations can be found in the Excel spreadsheet file containing the calculation results (in the sheet “Met. statistics”). It contains for each time-of-day period the percentage of occurrences in each meteo-class and the corresponding air temperature and relative humidity. More than this information, the turbulence is defined by the structure parameters $C_v^2 = 0.12\ m^{4/3}/s^2$ and $C_t^2 = 0.008\ K/s^2$. In the calculations, the railway line is assumed to have the direction North-South with the receiver placed east of the railway line. The train is assumed to move towards North.

Calculation of maximum noise levels which corresponds to time weighting Slow has been made according to Ref. [7] where it is stated that maximum noise levels should be determined for meteo-class 24.

In the calculation of the maximum level, each train is assumed to have a length of 300 m (same value is used for all train groups).

Railway tracks with a change in sound power level along the track

The test of the effect on maximum noise levels of a change in sound power level on a part of the railway track has been based on the input data for train type no. 1 (passenger trains IC3 or IR4) described above. The only difference is that calculations for a train length of 60 m as well as 300 m are included. All other calculation parameters and geometry are kept the same as described above for the test cases with constant sound power level along the track.

In the calculation, a track segment is included where the sound power is increased by 6 dB relative to the Nord2000 source data [2]. Test cases have been made for a segment length of 10 m (e. g. a switch) and 100 m (e. g. a bridge).

3. Test Case Calculation Results

Railway tracks with a constant sound power level along the track

The results of 16 cases (8 train categories and 2 distances) are given in the Excel file "Rail-Test_20180928" with one worksheet for each test case. (20180928 in the filename is the date September 28, 2018). An example of a sheet is shown in Appendix A. The results are:

- The yearly average of the noise exposure level L_{den} and the corresponding spectrum per one-third octave band (unweighted)

- The A-weighted maximum level L_{pAmaxS} with time weighting Slow and the corresponding spectrum per one-third octave band (unweighted)

- The absolute A-weighted maximum level L_{pAmax} defined as the maximum level if the source in the horizontal direction is a point source. This value is only for information and is not considered a part of the test (the number is shown on a grey background).

Besides the results, the sheet contains for each test case the traffic parameters and the propagation distance.

Railway tracks with a change in sound power level along the track

The results of 10 cases (eight cases of L_{pAmax} and two cases of L_{den}) are given in the Excel file "RailTestChangeInLW_20180928" grouped in two worksheets denoted MaxS and Lden. An example of a sheet is shown in Appendix B. In the worksheets, the calculated value of the noise indicator is shown as a function of the distance of the receiver along the railway track in 25 m steps (first column of the table) of each test case in the group. A distance value of 0 m indicates that the receiver is outside the midpoint of the segment with increased source power levels. Positive and negative distance values indicate that the receiver is North respectively South of the midpoint of the segment with an increase in sound power level.

4. Acceptable Deviation

To check whether a software provider has implemented the Nord2000 railway source data correctly, all the test examples in this report shall be calculated.

The A-weighted noise exposure level L_{den} shall not deviate by more than 1 dB from the calculated results in any example specified in the present report. In most cases the deviations can be kept within 0.5 dB. Deviations exceeding 0.5 dB should therefore give rise to increased awareness concerning possible errors in the software under test, and the reasons for the deviation should be explained.

The corresponding calculated one-third octave band spectra of L_{den} shall be compared to the one-third octave spectra in this report. Deviations less than 1 dB are in general acceptable for the sound level values in each frequency band. Deviations exceeding 1 dB in one frequency band shall be investigated. Special problems may occur at ground effect dips in the frequency spectrum where the uncertainty may increase. A shift in the dip may lead to a considerable sound level difference in a frequency band close to the dip. A shift in the dip frequency of one third octave will in general be considered acceptable in such cases.

Maximum noise levels can be expected to be more sensitive to local details in the calculations than the noise exposure levels. If the deviations of the maximum levels are within the limits defined for noise exposure levels the accuracy is considered acceptable without further explanation. If the limits are exceeded the deviation shall be investigated and an explanation shall be found. However, it is expected that it can be necessary to accept deviations twice the size of those defined above for noise exposure levels.

5. References

[1] H. J. Jonasson and Svein Storeheier, *Nord2000. New Nordic prediction method for rail traffic noise*, SP Report 2001:11, Borås 2001.

[2] D. Hoffmeyer, *Kildestyrkedata for togstøj til Nord2000 (Source data for railway noise in Nord2000)*, Miljøstyrelsen, Miljøprojekt Nr. 1014, 2005 (in Danish).

[3] B. Plovsing, *Nord2000. Comprehensive Outdoor Sound Propagation Model. Part 1: Propagation in an Atmosphere without Significant Refraction*, DELTA Acoustics & Vibration, Report AV 1849/00 (revised), Hørsholm, 2006.

[4] B. Plovsing, *Nord2000. Comprehensive Outdoor Sound Propagation Model. Part 2: Propagation in an Atmosphere with Refraction*, DELTA Acoustics & Vibration, Report AV 1851/00 (revised), Hørsholm, 2006.

[5] B. Plovsing, *Proposal for Nordtest Method: Nord2000 – Prediction of Outdoor Sound Propagation*, DELTA Acoustics, Report AV 1106/07 (revised), Hørsholm, January 2014.

[6] R. Eurasto, *Nord2000 for road traffic noise prediction. Weather classes and statistics*, VTT Research Report No. VTT-R-02530-06, Esbo 2006.

[7] B. Plovsing, *Revision of Nord2000 source model for predicting maximum noise levels from rail traffic*, Miljøstyrelsens Referencelaboratorium for Støjmålinger, Teknisk Notat J. nr. RL 14/16, Hørsholm 2016.

[8] B. Plovsing, *Nord2000 – Prediction of Outdoor Sound Propagation. Amendments to Report AV 1106/07*, DELTA Technical Report TC-xxxxxx, Hørsholm 2018 (to be published)

Appendix A

As an example, one case (train type no. 1, propagation distance 10 m) from the Excel workbook file “RailTest_20180928.xlsx” is shown below.

Nord2000 - Rail Traffic

Traffic parameters

Train type	1	
l(day)	11000	m per 24h
l(evening)	3000	m per 24h
l(night)	3000	m per 24h
l(max)	300	m
Speed	120	km/h

Propagation parameters

Distance	10	m

Calculated noise levels

Lden	67.70	dB
LpAmaxS	86.97	dB
LpAmax	94.70	dB

Calculated spectra

Freq.	Lden	LpmaxS
Hz	dB	dB
25	50.18	68.08
31.5	50.09	67.98
40	53.24	71.12
50	58.79	76.64
63	61.85	79.67
80	60.95	78.70
100	58.62	76.27
125	56.95	74.44
160	54.70	71.93
200	57.42	76.51
250	56.15	75.27
315	55.40	74.54
400	54.64	73.81
500	53.27	72.64
630	53.59	73.54
800	56.33	76.43
1000	58.76	78.47
1250	59.05	78.16
1600	58.70	77.76
2000	58.78	78.04
2500	56.67	75.56
3150	54.59	74.31
4000	52.08	69.88
5000	49.02	67.88
6300	45.33	64.84
8000	43.70	63.19
10000	42.64	61.12

Appendix B

As an example, the first worksheet with eight test cases from the Excel workbook file "RailTestChangeInLW_20180928.xlsx" is shown below. The second worksheet has the same format but contains only two test cases.

Nord2000 - Rail Traffic

Change in sound power level along the track

Noise indicator: LpAmaxS (dB)

Distance	d = 10 m				d = 100 m			
along	l(train) = 60 m		l(train) = 300 m		l(train) = 60 m		l(train) = 300 m	
track	l(segm) = 10 m	l(segm) = 100 m	l(segm) = 10 m	l(segm) = 100 m	l(segm) = 10 m	l(segm) = 100 m	l(segm) = 10 m	l(segm) = 100 m
-400	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-375	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-350	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-325	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-300	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-275	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-250	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-225	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-200	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
-175	85.64	85.64	86.97	86.97	69.41	69.41	73.87	74.07
-150	85.64	85.64	86.97	86.97	69.41	69.41	73.91	74.38
-125	85.64	85.64	86.97	86.97	69.41	69.41	73.96	74.96
-100	85.64	85.64	86.97	87.00	69.41	69.41	74.11	75.69
-75	85.64	85.70	86.98	87.16	69.41	70.38	74.18	76.67
-50	85.64	89.60	87.00	90.94	69.41	73.37	74.51	77.62
-25	85.80	91.62	87.13	92.93	71.10	75.12	74.62	78.26
0	89.97	91.64	91.97	92.96	71.45	75.41	74.76	78.56
25	85.80	91.62	87.13	92.93	71.10	75.12	74.62	78.26
50	85.64	89.60	87.00	90.94	69.41	73.37	74.51	77.62
75	85.64	85.70	86.98	87.16	69.41	70.38	74.18	76.67
100	85.64	85.64	86.97	87.00	69.41	69.41	74.11	75.69
125	85.64	85.64	86.97	86.97	69.41	69.41	73.96	74.96
150	85.64	85.64	86.97	86.97	69.41	69.41	73.91	74.38
175	85.64	85.64	86.97	86.97	69.41	69.41	73.87	74.07
200	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
225	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
250	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
275	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
300	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
325	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
350	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
375	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87
400	85.64	85.64	86.97	86.97	69.41	69.41	73.87	73.87