Appendix A15.3: Noise and Vibration Calculation and Model Inputs and Assumptions

1.1 Noise emission database of construction plant equipment

1.1.1 Part 1 of BS 5228:2009+A1:2014 provides suitable methods for the calculation of noise from construction activities, including basic information regarding noise levels from a range of construction equipment. The construction noise levels for this assessment have been calculated in accordance with BS 5228-1:2009+A1:2014 Annex F and sound emission levels, associated with the indicative list of construction plant and equipment derived for this assessment, have been sourced from BS 5228-1:2009+A1:2014 Annex C. Items of plant have been aligned with equivalent items provided in BS5228-1 to determine their noise emission. The selected A-weighted sound power levels have then been corrected so to consider the 'Percentage On-time' (portion of time in which the equipment is operating at its maximum power), and 'Duration of Activity' (amount of time in relation to the 'Shift Duration' in which the equipment is expected to operate).

1.1.2 Table A15.3-1 lists the assumed construction plant and equipment used as the noise source inputs for the construction noise model. It should be noted that the lists below do not form the full complement of plant and equipment for each construction activity. The table below contains those items of plant likely to be present during each construction activity operating at the same time and at the closest point to a receptor. This can therefore be considered for the noise calculations to be a largely single homogenous source for the type of works described.

Table A15.3-1: Assumed List of Noise Emission Data for Construction Plant and Equipment

Activity	BS 5228 / Source[1]		Plant Description	Qty	% On-Time[2]	Shift Duration, T (hrs)	Duration of Activity (hrs)	% Activity Time[3]	Lw (dB(A)) from Single Item[4]
	BS 5228 Table	BS 5228 Ref. No.							
Compound Construction	C.2.	24	Tracked excavator	1	30%	12	10	83%	95.0
	C.2.	34	Lorry	1	25%	12	10	83%	101.2
	C.5.	27	Vibratory roller	1	25%	12	10	83%	88.2
	C.5.	28	Vibratory roller	1	25%	12	10	83%	98.2
	C.5.	29	Vibratory compacter	1	20%	12	10	83%	102.2
	C.4.	53	Lorry with lifting boom	1	30%	12	10	83%	99.0
Compound Operation	C.4.	76	Diesel generator	2	80%	12	10	83%	90.2
	C.2.	34	Lorry	2	40%	12	10	83%	106.2
	C.4.	53	Lorry with lifting boom	2	30%	12	10	83%	102.0
Excavation	C.5.	18	Tracked excavator	2	30%	12	10	83%	105.0
	C.4.	1	Articulated dump truck	2	35%	12	10	83%	106.7
	C.2.	10	Dozer	2	30%	12	10	83%	105.0
	C.2.	34	Lorry	2	30%	12	10	83%	105.0
Backfill & Compaction	C.4.	1	Articulated dump truck	2	35%	12	10	83%	106.7
	C.2.	10	Dozer	2	30%	12	10	83%	105.0
	C.5.	20	Vibratory roller	2	40%	12	10	83%	101.2
	C.2.	37	Roller	2	40%	12	10	83%	105.2

Activity	BS 5228 / Source[1]		Plant Description	Qty	% On-Time[2]	Shift Duration, T (hrs)	Duration of Activity (hrs)	% Activity Time[3]	Lw (dB(A)) from Single Item[4]
	BS 5228 Table	BS 5228 Ref. No.							
	C.5.	18	Tracked excavator	1	25%	12	10	83%	101.2
Bored Piling	C.5.	18	Tracked excavator	1	35%	12	10	83%	102.6
	C.3.	14	Large rotary bored piling rig	2	50%	12	10	83%	110.2
	C.4.	43	Wheeled mobile crane	1	25%	12	10	83%	91.2
	C.4.	26	Concrete pump + truck	1	40%	12	10	83%	98.2
	C.2.	34	Lorry	1	20%	12	10	83%	100.2
Sheet Piling	C.5.	18	Tracked excavator	1	30%	12	10	83%	102.0
	C.3.	8	Vibratory piling rig	1	40%	12	10	83%	111.2
	C.2.	34	Lorry	1	20%	12	10	83%	100.2
	C.2.	35	Telescopic handler	1	25%	12	10	83%	92.2
Piling Platform	C.2.	34	Lorry	2	45%	12	10	83%	106.8
	C.5.	24	Vibratory roller	2	50%	12	10	83%	111.2
	C.5.	18	Tracked excavator	1	35%	12	10	83%	102.6
Pile Cap	C.2.	24	Tracked excavator	1	30%	12	10	83%	95.0
	C.1.	1	Breaker mounted on wheeled backhoe	1	30%	12	10	83%	114.0
	C.4.	27	Concrete mixer truck	1	30%	12	10	83%	101.0

Activity	BS 5228 / Source[1]		Plant Description	Qty	% On-Time[2]	Shift Duration, T (hrs)	Duration of Activity (hrs)	% Activity Time[3]	Lw (dB(A)) from Single Item[4]
	BS 5228 Table	BS 5228 Ref. No.							
	C.4.	33	Poker vibrator	1	15%	12	10	83%	97.0
	C.4.	70	Petrol hand-held circular saw	1	10%	12	10	83%	108.2
Installation of Pre-Cast Structural Elements	C.11.	7	Lorry	2	30%	12	10	83%	104.0
	C.4.	38	Wheeled mobile telescopic crane	1	50%	12	10	83%	102.2
	C.4.	54	Telescopic handler	1	30%	12	10	83%	101.0
	C.4.	57	Lifting platform	2	40%	12	10	83%	93.2
Formwork & Reinforcing	C.4.	54	Telescopic handler	1	30%	12	10	83%	101.0
	C.4.	57	Lifting platform	2	40%	12	10	83%	93.2
	Measured Data		Circular Saw	1	20%	12	10	83%	96.2
	Measured Data		Paslode Nail Gun	1	5%	12	10	83%	106.2
	C.4.	70	Petrol hand-held circular saw	1	10%	12	10	83%	108.2
Concrete	C.4.	54	Telescopic handler	1	30%	12	10	83%	101.0
	C.4.	26	Concrete pump + truck (idling)	1	50%	12	10	83%	99.2
	C.4.	33	Poker vibrator	1	15%	12	10	83%	97.0
	C.4.	35	Vibratory tamper	1	10%	12	10	83%	80.2

Activity	BS 5228 / Source[1]		Plant Description	Qty	% On-Time[2]	Shift Duration, T (hrs)	Duration of Activity (hrs)	% Activity Time[3]	Lw (dB(A)) from Single Item[4]
	BS 5228 Table	BS 5228 Ref. No.							
	C.4.	19	Cement mixer truck	1	25%	12	10	83%	92.2
Surfacing	C.5.	31	Asphalt paver (+ tipper lorry)	1	40%	12	10	83%	100.2
	C.5.	19	Road roller	2	25%	12	10	83%	104.2
	C.2.	34	Lorry	2	25%	12	10	83%	104.2
	Manufacturer's Data		JCB 2CX Airmaster	1	25%	12	10	83%	94.2
	C.1.	6	Hand held pneumatic breaker	1	15%	12	10	83%	102.0
Excavation Low Headroom	C.4.	67	Mini tracked excavator	2	40%	12	10	83%	100.2
	C.2.	24	Tracked excavator	1	40%	12	10	83%	96.2
	C.4.	6	Dumper	2	35%	12	10	83%	104.7
	C.5.	18	Tracked excavator	1	30%	12	10	83%	102.0
	C.2.	34	Lorry	2	25%	12	10	83%	104.2
Piling Low Headroom	C.4.	67	Mini tracked excavator	1	40%	12	10	83%	97.2
	C.3.	18	Mini piling rig	2	50%	12	10	83%	102.2
	C.3.	19	Compressor for mini piling rig	1	50%	12	10	83%	99.2
	C.4.	26	Concrete pump + truck	1	40%	12	10	83%	98.2
	C.2.	34	Lorry	1	25%	12	10	83%	101.2

Activity	BS 5228 / Source[1]		Plant Description	Qty	% On-Time[2]	Shift Duration, T (hrs)	Duration of Activity (hrs)	% Activity Time[3]	Lw (dB(A)) from Single Item[4]
	BS 5228 Table	BS 5228 Ref. No.							
Scaffolding	C.11.	4	Lorry	1	30%	12	10	83%	105.0
	C.5.	18	Tracked excavator	1	35%	12	10	83%	102.6
	C.2.	34	Lorry	1	25%	12	10	83%	101.2
	C.4.	57	Lifting platform	1	25%	12	10	83%	88.2
	Measured Data		Impact Wrench	2	10%	12	10	83%	102.2
Demolition & Lifting Out	Measured Data		Wire Saw	1	60%	12	10	83%	101.1
	C.4.	76	Diesel generator	2	80%	12	10	83%	90.2
	C.4.	41	Mobile telescopic crane	1	30%	12	10	83%	93.0
	C.5.	18	Tracked excavator	1	25%	12	10	83%	101.2
	C.1.	3	Pulveriser mounted on excavator	1	30%	12	10	83%	102.0
	C.11.	4	Lorry	1	25%	12	10	83%	104.2
Breaking Out Concrete	C.1.	3	Pulveriser mounted on excavator	1	30%	12	10	83%	102.0
	C.1.	1	Breaker mounted on wheeled backhoe	1	35%	12	10	83%	114.6
	C.5.	18	Tracked excavator	1	25%	12	10	83%	101.2
	C.2.	34	Lorry	1	30%	12	10	83%	102.0

1.2 Input Parameters for Calculation of Construction Vibration Levels

1.2.1 Vibration levels from vibratory compaction and sheet piling have been calculated using the methodologies contained in BS 5228-2. Table A15.3-2 shows the input parameters used for the vibration level calculations.

Table A15.3-2: Input Parameters of Calculation of Vibration Levels

Parameter	Variable Input	Definition
Vibratory compaction during start up and run down – Higher Vibration Amplitude Setting		
K_s	65	scaling factor (50% probability of predicted value being exceeded)
n_d	1	number of vibrating drums
A	1.7	maximum amplitude of drum vibration (mm)
x	Variable	distance to representative receptor (m)
L_d	2.13	width of vibrating roller drum (m)
Vibratory compaction during steady state – Higher Vibration Amplitude Setting		
K_s	75	scaling factor (50% probability of predicted value being exceeded)
n_d	1	number of vibrating drums
A	1.7	maximum amplitude of drum vibration (mm)
x	Variable	distance to representative receptor (m)
L_d	2.13	width of vibrating roller drum (m)
Vibratory compaction during start up and run down – Lower Vibration Amplitude Setting		
K_s	65	scaling factor (50% probability of predicted value being exceeded)
n_d	1	number of vibrating drums
A	0.9	maximum amplitude of drum vibration (mm)
x	Variable	distance to representative receptor (m)
L_d	2.13	width of vibrating roller drum (m)
Vibratory compaction during steady state – Lower Vibration Amplitude Setting		
K_s	75	scaling factor (50% probability of predicted value being exceeded)
n_d	1	number of vibrating drums

Parameter	Variable Input	Definition
A	0.9	maximum amplitude of drum vibration (mm)
x	Variable	distance to representative receptor (m)
L_d	2.13	width of vibrating roller drum (m)
Vibratory Sheet Piling		
K_v	60	scaling factor for 50% probability of predicted value being exceeded
δ	1.3	constant associated with all types of operation (steady state and start up and run down)
x	Variable	distance to representative receptor (m)
Percussive Sheet Piling		
K_p	5	scaling factor for piles at refusal
W	85	nominal hammer energy, in joules (J)
x	Variable	distance to representative receptor (m)

1.3 Operational Noise model Inputs and assumptions

Operational Road Traffic Noise Model

1.3.1 The CadnaA noise model input data includes the following inputs and assumptions:

- Traffic data:
  - 18-hour AAWT traffic flow;
  - 18-hour AAWT percentage of HGVs (defined as any vehicle with an unladen weight greater than 3.5 tonnes); and
  - traffic speeds derived in accordance with the requirements of DMRB LA 111.
- Topography:
  - existing topography for the study area comprised of survey data undertaken for the proposed scheme and supplemented with a 3D digital terrain model (DTM) using 5m resolution height data; and
  - proposed topography (3D DTM data taken from the proposed scheme design).
- Road alignment, width and gradient.
- Road surfaces:
  - existing road surface types for Do-Minimum scenario in the opening year are assumed to be impervious bitumen, such as hot rolled asphalt (HRA);

  - in accordance with DMRB LA 111, for HRA, a surface correction -0.5dB(A) has been used for mean speeds greater than or equal to 75km/h and -1dB(A) where the mean traffic speed is less than 75km/h;
  - road surface types for the existing A9 in the Do-Minimum scenario in the future assessment year are assumed to be low noise road surfacing (LNRS) and all other roads are assumed to be impervious bitumen, such as HRA;
  - In accordance with DMRB LA 111, for LNRS, a surface correction -3.5dB(A) has been used for speeds greater than 75km/h and -1dB(A) where the mean traffic speed is less than or equal to 75km/h; and
  - all new roads constructed on the mainline and slip roads of the proposed scheme will be LNRS; and
  - all other roads of the proposed scheme will be HRA.
- Ground absorption factors have been determined through analysis of the OS MasterMap Topography Layer®:
  - G=1 (soft, acoustically absorbent ground) for open natural land, grass verges and forested areas;
  - G=0.5 (mixed ground) for residential areas, representing a mix of drives, paths, paved and garden areas; and
  - G=0 (hard, acoustically reflective ground) for roads, pavements, water and open manmade land, such as car parks.
- Existing building footprints have been extracted from OS MasterMap Topography Layer®:
  - small buildings, defined as those which have a total footprint area of less than 20m^2, are not included in the noise model;
  - single storey buildings are assumed to be 3.5m high and two storey buildings are assumed to be 6m high, with a further 2.5m added per storey for taller buildings; and
  - all buildings are assumed to be fully reflective and have an absorption factor of 0.
- The proposed scheme includes retaining walls in some locations, which have been modelled as fully reflective (i.e. have an absorption factor of 0) barriers, to account for the potential increase in road traffic noise due to acoustic reflections from the walls.
- The proposed scheme includes acoustic barriers or other walls and fences that would perform as acoustic barriers. The have been modelled as fully reflective (i.e. have an absorption factor of 0) or fully absorptive (i.e. have an absorption factor of 1) barriers as appropriate.

1.3.2 In line with CRTN, a minimum traffic speed of 20km/h and maximum traffic speed of 130km/h are used in the noise models where the traffic model predictions provide speeds less than or greater than these.

1.3.3 No minimum traffic flow threshold has been imposed for roads with very low traffic flows (less than 1,000 vehicles per day (18-hour AAWT)), as excluding such roads or adjusting the traffic flows so that they are within the range of validity for CRTN both have the potential to obscure or exaggerate noise changes. Accordingly, it is considered that while noise levels calculated for roads with flows of less than 1,000 vehicles per day may be subject to increased error, the approach adopted is appropriate for the purposes of the operational noise assessment and avoids the potential for effects being missed.

Operational Replacement Dunkeld & Birnam Station Cark Park Noise Model

1.3.4 Noise levels have been calculated for station car park operational activities using the CadnaA noise modelling software in accordance with ISO 9613-2 (International Organization for Standardization, 2024). The prediction of noise within the CadnaA model aims to represent operational noise levels that could occur within a worst-case period for daytime operation. The assessment period for daytime operation is 1 hour during daytime (07:00 – 23:00).

1.3.5 The following activities allow for a worst-case assessment and have been modelled:

- Cars arriving and departing; and
- Cars idling and car doors opening and closing.

1.3.6 In order to present a worst case scenario, traffic information provided by the traffic engineers indicates that a conservative peak daytime average hourly traffic flow is eight car movements (six cars arriving and two cars leaving the car park) per hour.

1.3.7 The modelling work assumes that vehicular activity would be evenly distributed across the areas of use, defined by the car park layout. Stationary car sources are distributed evenly across the area of the car parks and moving sources follow the route cars would take around the car park.

1.3.8 All vehicle noise sources have been modelled at a height of 1 m above ground, to account for a worst-case vehicle combined engine and exhaust height. The majority of effective source positions for the noise emissions are likely to be closer to the ground and therefore would potentially benefit from greater ground and screening attenuation than currently assumed.

1.3.9 The assessment of car alarms has not been included in the operational station noise assessment. Car alarm sound is considered to be atypical and is likely to be an infrequent event which is not representative of normal operation of the car park.

1.3.10 The activities and assumed sources associated with the car park operation are presented in Table A15.3-3. Sound power level presented to car movement is for one vehicle pass-by. The number of vehicle movements is incorporated directly in the noise model.

Table A15.3-3: Car Park Activity List with Associated Sources and Sound Power Levels

Activity	Source	% On-time	No. of Sources	dB L_{wA}	Corrected dB L_{wA}	Activity dB L_{wA}
Car Park Stationary Sources	Car Door Use	1	8	89	78	79
	Car Idle	5	8	76	72	
Car Movement	Car Movement	N/A	1	90	90	90

1.3.11 The octave band sound power levels associated with each activity assumed in the operation noise assessment are presented in Table A15.3-4.

Table A15.3-4: Octave Band Sound Power Levels for each Car Park Activity

Activity	Linear Octave Band Sound Power Levels, dB by 1/1 Centre Band Frequency, Hz								dB L_{wA}
	63	125	250	500	1000	2000	4000	8000	
Car Park Stationary Sources	79	76	72	75	74	73	70	62	79
Car Movement	102	97	92	85	83	79	77	70	90