Review of the concept, test data and derivation procedures of vibration proposal

EVS-GTR 19th

China

Contents

Information of tested vehicles

M1 N1 group:
2 mini cars，3 cargo vans，11 passenger cars, including EV, PHEV and HEV.
Wheelbase from 1765mm to 3850mm






Type		Wheelbase（mm）	pack location
mini car	EV	1765	bottom
mini car	EV	2150	bottom
passenger car	EV	2490	bottom
passenger car	EV	2500	bottom
passenger car	EV	2650	bottom
passenger car	EV	2650	bottom
passenger car	PHEV	2670	bottom
passenger car	EV	2670	bottom
passenger car	EV	2700	bottom
passenger car	HEV	2700	Trunk
cargo van	EV	2700	bottom
passenger car	EV	2720	bottom
passenger car	HEV	2775	Trunk
passenger car	PHEV	2850	Trunk
cargo van	EV	3050	bottom
cargo van	EV	3850	bottom

Information of tested vehicles

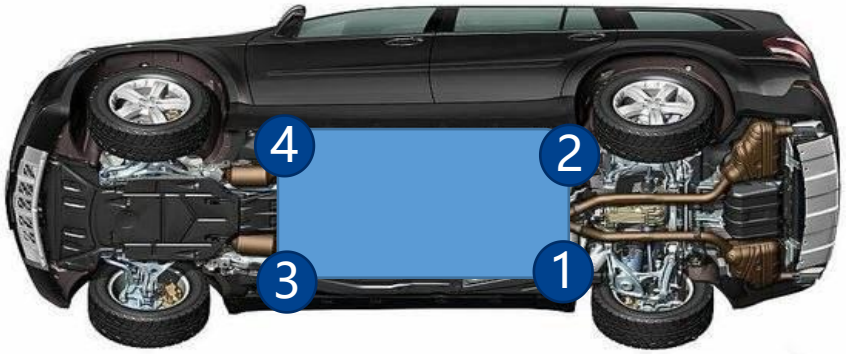
Bus group:
7 buses, including EV, PHEV and FCEV.

Type		Length（mm）	Pack location
bus	EV	12000	bottom & back
bus	EV	12000	top
bus	PHEV	10500	top
bus	PHEV	8545	Engine compartment
bus	EV	8010	bottom
bus	EV	10480	bottom
bus	FCEV	12000	bottom

Test layout, Sensor installation and measurement

- Sensor layout principle: focus on the installation of fixed parts fixed position
- At least 4 sensors are fixed distributed at different installation points

N.O.	Position	Vehicle Direction	Sensor direction	Channels
2601	Right rear	X	X	AI-0
		Y	Z	AI-1
		Z	Y	AI-2
2602	Left rear	X	X	AI-3
		Y	Z	AI-4
		Z	Y	AI-5
2603	Right forward	X	X	AI-6
		Y	Y	AI-7
		Z	Z	AI-8
2604	Left forward	X	X	AI-9
		Y	Y	AI-10
		Z	Z	AI-11



Introduction to test roads and methods

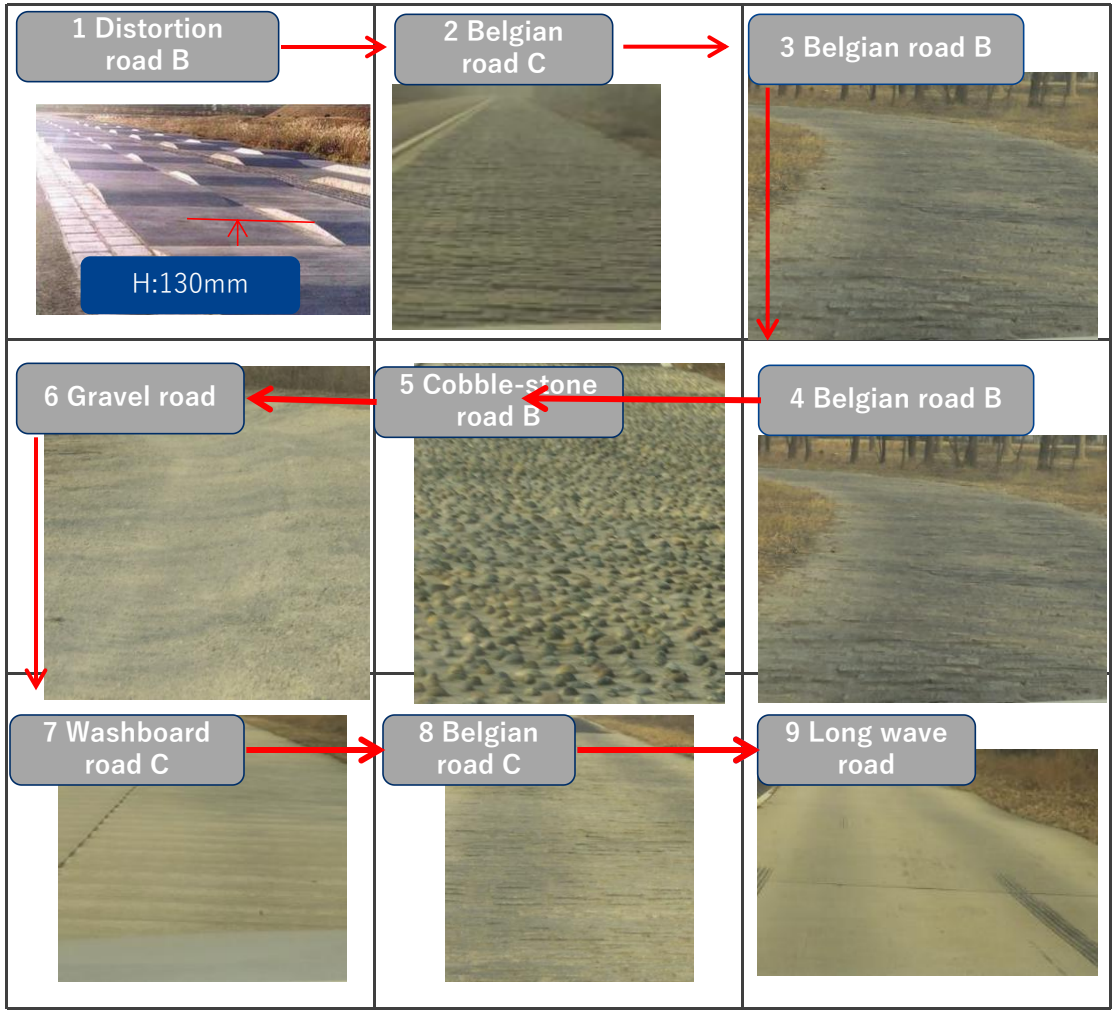
- Test specification
  - Tongxian test ground car product stereotypes reliability driving test specification (2000 edition)
  - It is based on the characteristics of China's road conditions, and widely recognized and used in vehicle type test in China
  - The test route, speed, tire pressure, weight and other conditions were set according to the test specification

Introduction to test roads and methods

■ Rough roads and test procedure

For passenger car

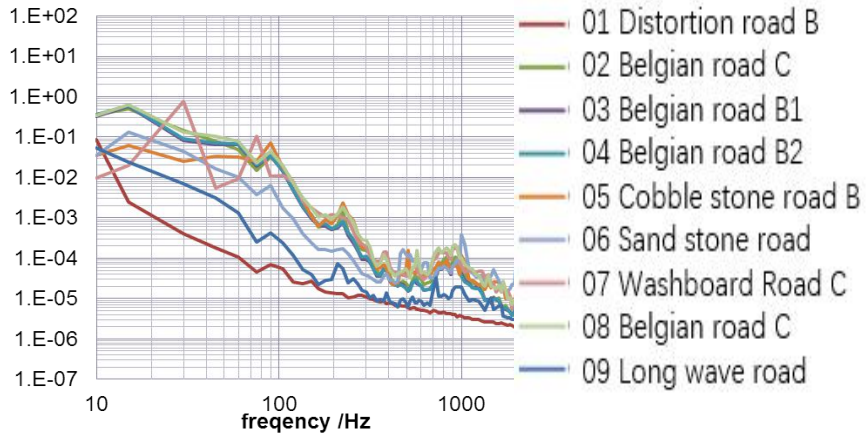
Seq.	Rough roads	length (m)	%	Vehicle speed (km/h)	Test times
1	Twisting road B	85	2.02%	10	3
2	Belgian road C	300	7.14%	40	
3	Belgian road B	989	23.53%	50	
4	Belgian road B	989	23.53%	50	
5	Cobble-stone road B	335	7.97%	50	
6	Gravel road	815	19.39%	40	
7	Washboard Road C	300	7.14%	50	
8	Belgian road C	300	7.14%	50	
9	Long wave road	90	2.14%	50	

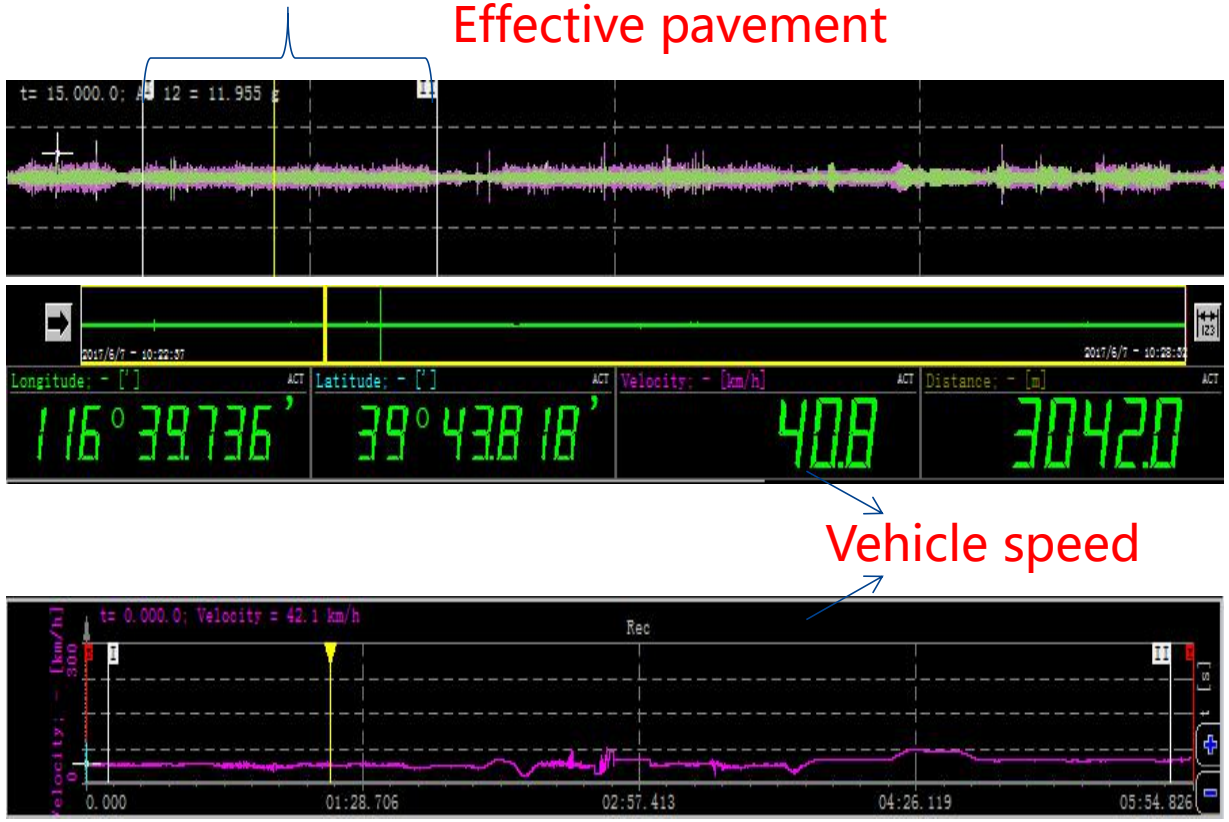


Test data and derivation procedures

- Time domain data transform into frequency domain data

Only the data on the rough roads were extracted.



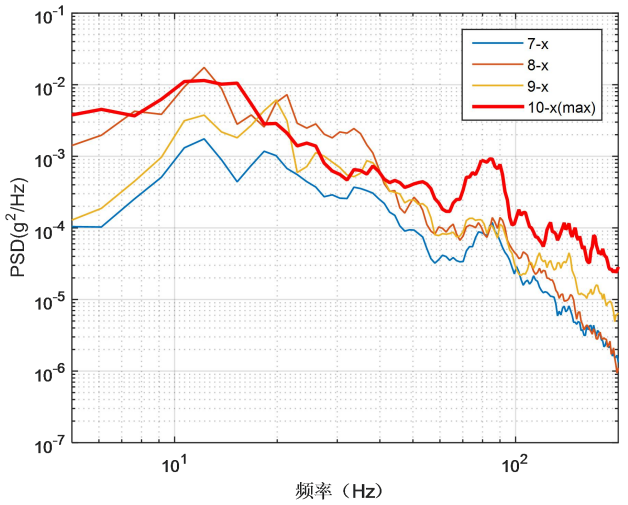


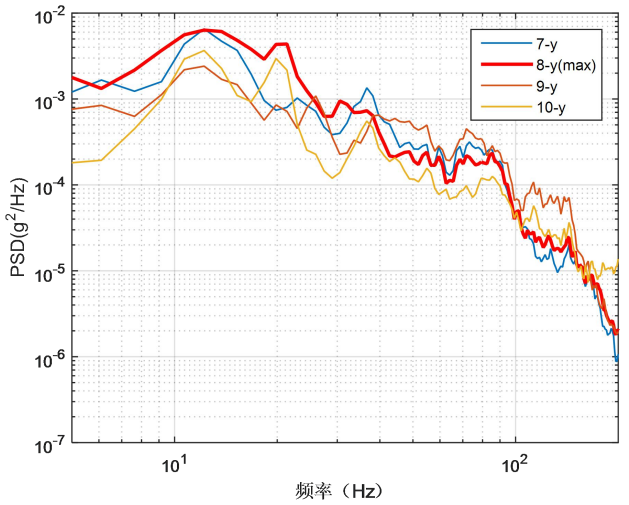
● Analytical conditions

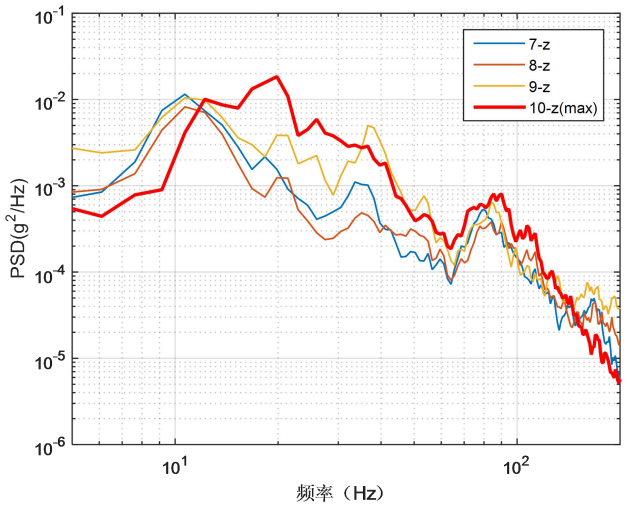
▪Frequency resolution	1Hz
▪Window function	Hanning
▪Average processing	Arithmetic mean
▪Frequency Range	5–200Hz

Test data and derivation procedures

- Because each vehicle is equipped with multiple sensors, for each kind of road, we choose the data of the sensor with the maximum RMS as the data of the road.







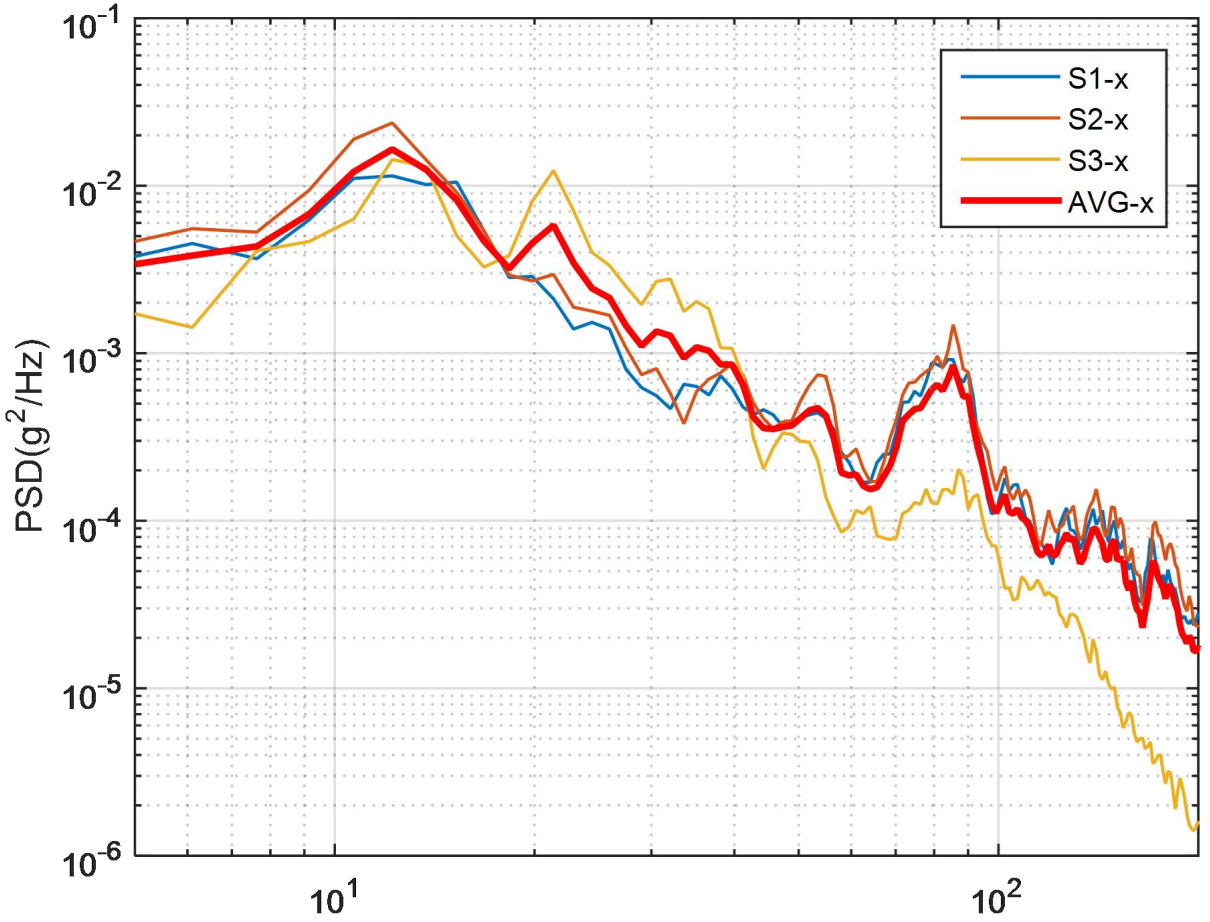
Circle	Sensor No.	X energy (g)
S1	7#	0.158
	8#	0.391
	9#	0.259
	10#	0.405

Circle	Sensor No.	Y energy (g)
S1	7#	0.270
	8#	0.320
	9#	0.232
	10#	0.208

Circle	Sensor No.	Z energy (g)
S1	7#	0.311
	8#	0.275
	9#	0.406
	10#	0.488

Test data and derivation procedures

- Each vehicle has been tested three times in the whole test site, that is to say, each road has been tested three times. We take the average value of three times of tests for each road as the vibration data of the road.



Test data and derivation procedures

- According to the test specifications, different vehicles need to be tested many times on the test road, we need to conduct 714 loops for passenger cars.

One loop (passenger car)

		①	②	③=①/②/1000
Seq.	Rough roads	length（m）	Vehicle speed (km/h)	Driving time (h)
1	Twisted road B	85	10	0.0085
2	Belgian road C	300	40	0.0075
3	Belgian road B	989	50	0.024725
4	Belgian road B	989	50	0.024725
5	Cobble-stone road B	335	50	0.0067
6	Gravel road	815	40	0.020375
7	Washboard Road C	300	50	0.006
8	Belgian road C	300	50	0.0075
9	Long wave road	90	50	0.0018

Passenger car X=714;
Minicar X=476
Cargo Van X=1274
Bus X=882

Extended to required distance

①*X	③*X
total distance	total time
60690	6.069
214200	5.355
706146	17.65365
706146	17.65365
239190	4.7838
581910	14.54775
214200	4.284
214200	5.355
64260	1.2852
3000.942km	**76.98705h**

Total rough road driving

Test data and derivation procedures

- To accelerate the test time to 12h

A.6.2 Outline

A typical failure mode due to vibration stress is fatigue. The equivalent fatigue time or vibration intensity level can be calculated using Formula A.1:

$$\frac{W_1}{W_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{m}} \qquad \text{(A.1)}$$

where

W_1 is the vibration acceleration level 1;

W_2 is the vibration acceleration level 2;

T_1 is the endurance testing time 1;

T_2 is the endurance testing time 2;

m is the acceleration coefficient.

m can have different numerical values depending on the material (usually from 3 to 9). The general value of the metal fatigue in random vibration is m = 4 but, as DUT consists of various components, m = 5 was adopted.

Refer to ISO DIS 19453-3

Test data and derivation procedures

- To accelerate the test time to 12h

200Hz	before Accelerated calculation ①			after Accelerated calculation②	
NO	Bad road	Vibration energy(g)	Life time(h)	MAX-Vibration energy(g)	NEW-Life time(h)
1	Dis				
2	B				
3	B				
4	B				
5	Cobb				
6	Sa				
7	Wa				
8	B				
9	L				

6Hz	before Accelerated calculation ①			after Accelerated calculation②	
NO					
1					
2					
3					
4					
5					
6					
7					
8					
9					

5Hz	before Accelerated calculation ①			after Accelerated calculation②	
NO	Bad road	Vibration energy(g)	Life time(h)	MAX-Vibration energy(g)	NEW-Life time(h)
1	Distortion road B	0.32835805	6.117	0.79436445	0.073820642
2	Belgian road C	0.68983775	5.397	0.79436445	2.665558393
3	Belgian road B	0.68195701	14.234	0.79436445	6.637628641
4	Belgian road B	0.62569791	14.234	0.79436445	4.315702337
5	Cobble-stone road B	0.16758758	4.318	0.79436445	0.001804649
6	Sand stone road	0.25275621	14.68	0.79436445	0.047878025
7	Washboard Road C	0.1847631	4.318	0.79436445	0.002939135
8	Belgian road C	0.79436445	4.318	0.79436445	4.31
9	Long wave road	0.25247094	1.295	0.79436445	0.0041997
	Total		68.91	③ 0.79436445	18.06753161
				④Regularization 0.770824848	12

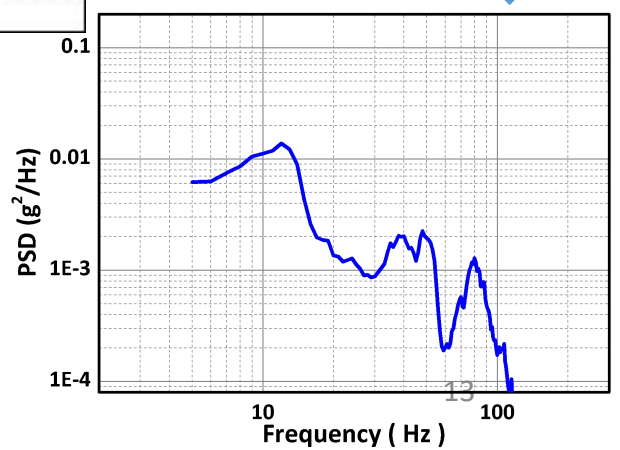
Frequency (Hz)	PSD (g)²/Hz
5	0.60221
6	0.71665
7	0.82560
8	1.01077
. . .	. . .
198	0.0016
199	0.0017
200	0.0016

- miner' law (①→②、③→④)

$$\frac{W_1}{W_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{m}}$$

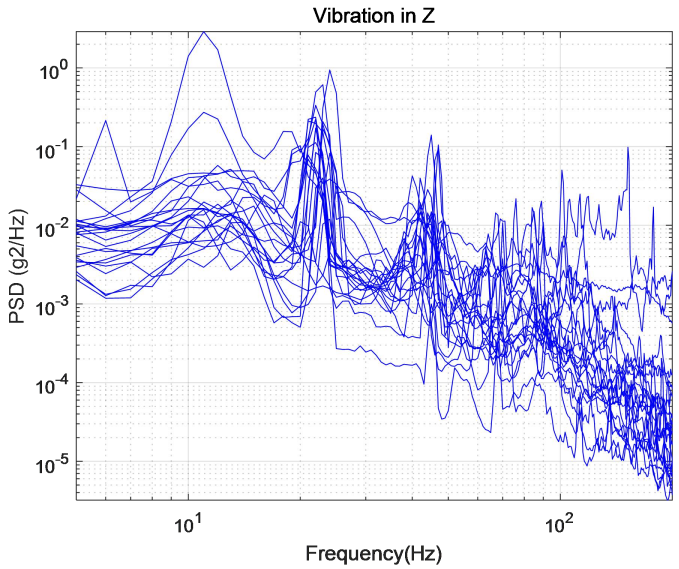
- The relationship between RMS and PSD is as follow:

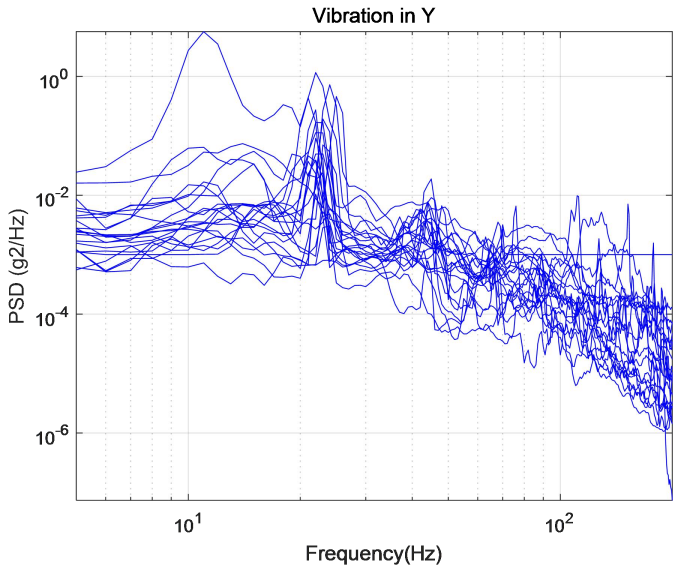
$$(g)_{\mathrm{rms}} = \sqrt{\Sigma(PSD \times \Delta Hz)}$$

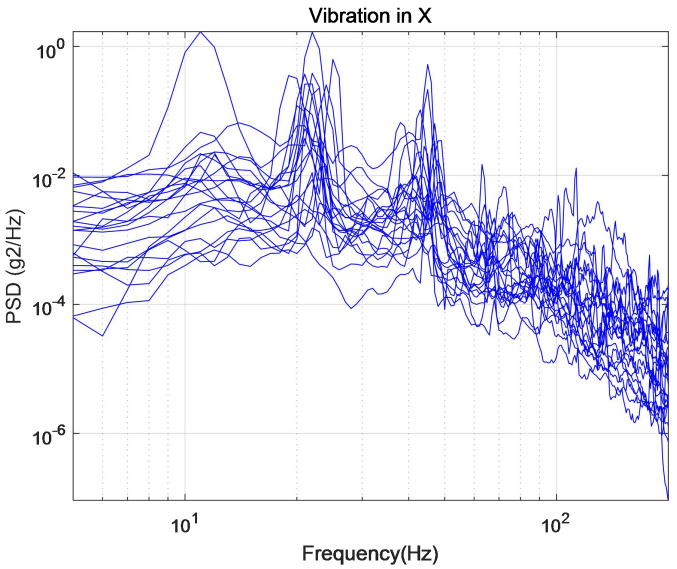


Test data and derivation procedures

- Then we get the PSD of 12h of all tested vehicles
- The peaks were caused by corrugation road， how to deal with them?
- How to choose the vibration test conditions?





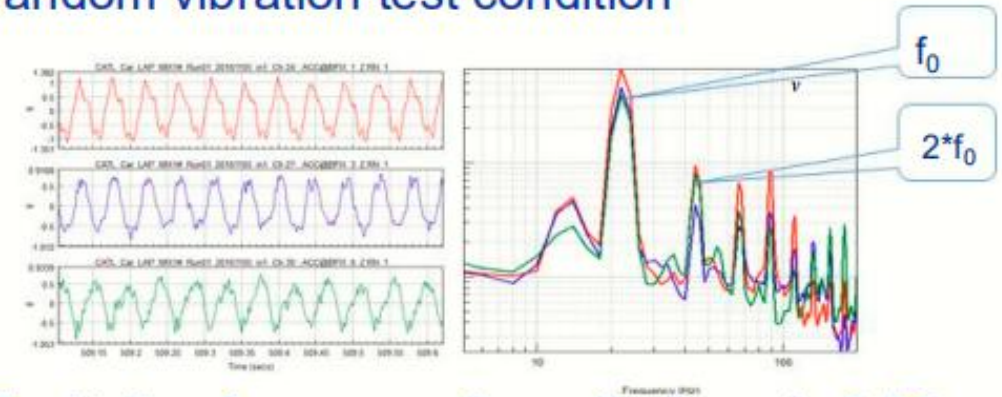


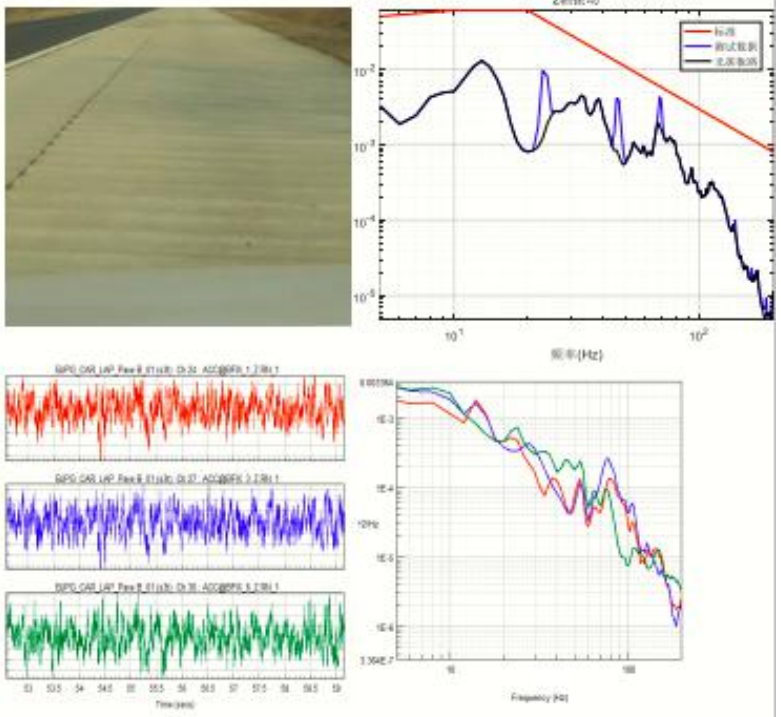
Test data and derivation procedures

- The peaks were caused by corrugation road

1. Corrugation road

- ✓ The data of corrugation road was extracted separately to carry out the constant frequency vibration, and the other roads surface data were developed to obtain random vibration test condition



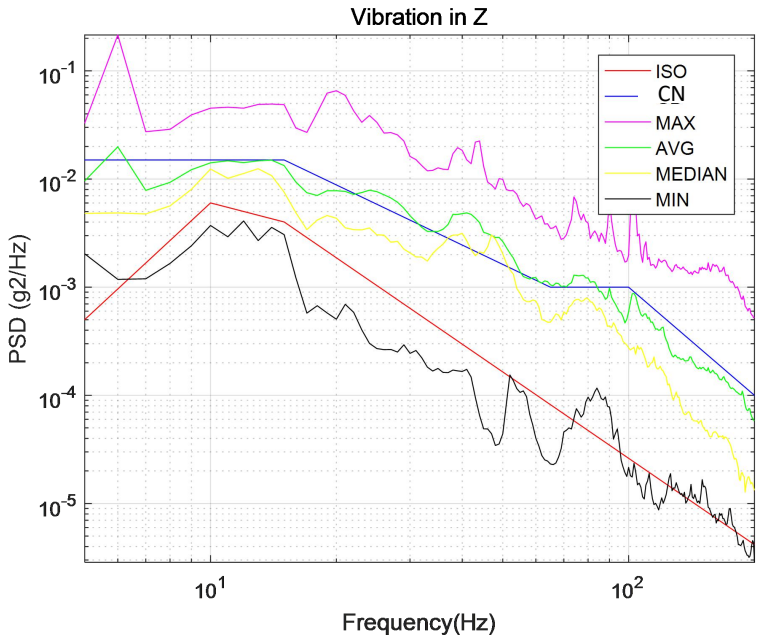


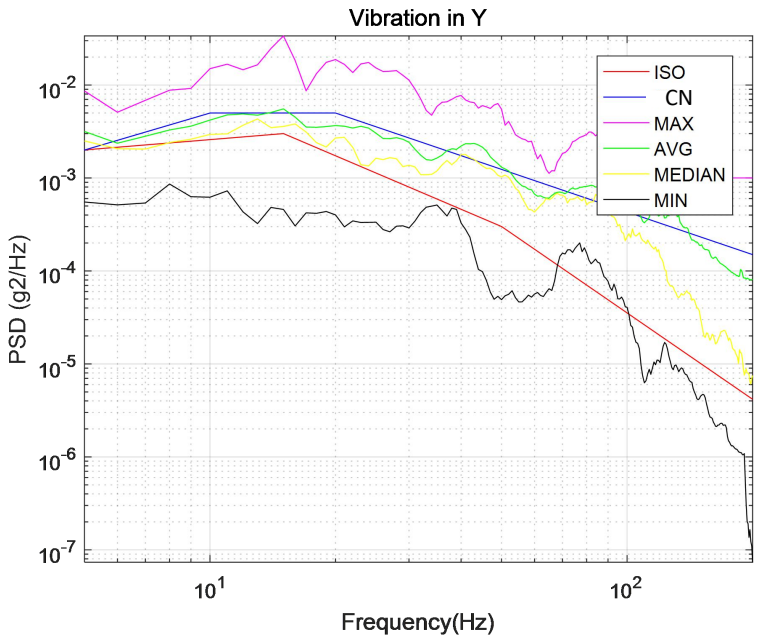
- ✓ Excitation frequency $f = v/\lambda$, here λ=0.58m

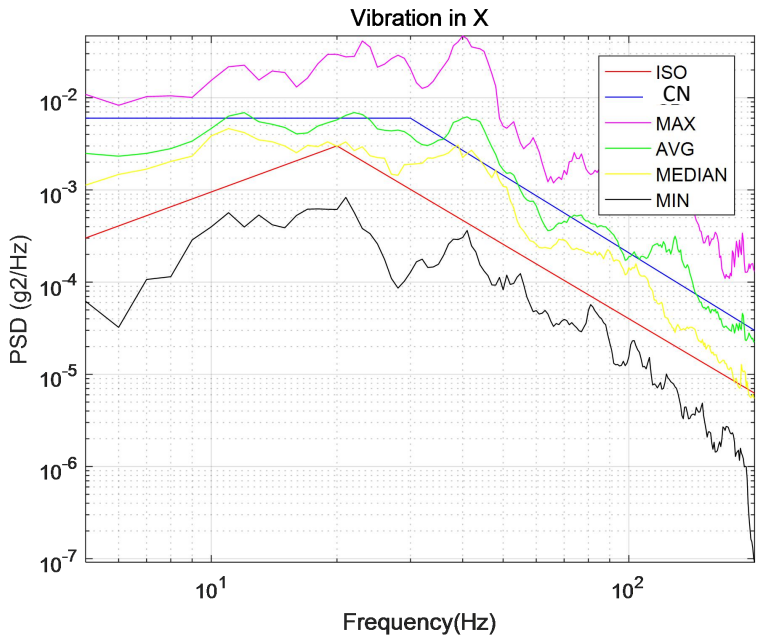
v(km/h)	10	20	30	40	50	60	70
f(Hz)	4.8	9.6	14.4	19.2	24.0	28.7	33.5

Vibration test conditions

- The results and recommended vibration test conditions







Direction	MAX	AVG	CN proposal	Median	ISO 6469-1	MIN
Z	1.3468	0.6364	0.6364	0.4821	0.2647	0.2060
Y	0.8922	0.4378	0.4378	0.3539	0.2520	0.1486
X	1.1094	0.4910	0.4910	0.3568	0.2343	0.1253

Thanks for your attention!