Foreword

According to the requirements of Document JIANBIAO [2006] No.136 issued by the Ministry of Housing and Urban-Rural Development (MOHURD) of the People's Republic of China- "Notice on Printing and Distributing 'the Development and Revision Plan of National Engineering Construction Standards in 2006' ", this code is completed by Electronic Engineering Standards Quota Station of Electronic Industry Standardization Institute of Ministry of Industry and Information Technology of the People's Republic of China and China Electronic Engineering Design Institute together with relevant units.

During the development of this code, the compiling group combined engineering investigations with researches and discussions again and again, and based on extensive advices, the final draft has been determined after reviews.

This code consists of 8 chapters and 2 appendixes, covering general provisions, terms, basic requirements, allowable value of vibration of precision instrument and equipment, planning and design, anti-microvibration of building structures, isolation design, acceptance of constructional quality of anti-microvibration engineering.

The provisions printed in bold type are mandatory ones and must be implemented strictly.

The Ministry of Housing and Urban-Rural Development of the People's Republic of China is in charge of administration of this code and explanation of its mandatory provisions. The Ministry of Industry and Information Technology is responsible for its routine management, and China Electronics Engineering Design Institute is in charge of explanation of specific technical contents. All the relevant organizations are kindly requested to accumulate engineering practices and sum up experiences during the implementation of this code. If revisions and supplementations are needed, relevant opinions and advices are suggested to be posted to the Department of Technological Quality of China Electronics Engineering Design Institute (Address: Beijing 307 Mailbox, Postcode: 100840) for future revision references.

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Contents

1 General provisions

1.0.1 In order to standardize the survey, design, and acceptance of constructional quality of anti-microvibration engineering in the electronics industry, this code is established to satisfy the microvibration environment requirements in precision equipment and instruments, with advanced technology, economic appropriateness, reliable operation and energy saving.

1.0.2 This code is applicable for anti-microvibration design, construction and quality acceptance of new construction and renovation of electronic industrial plants and testing stations.

1.0.3 In addition to the requirements in this code, design, construction, and quality acceptance of anti-microvibration engineering shall comply with those stipulated in the current relevant standards of the nation.

2 Terms

2.0.1 Micro-vibration

Environment vibration with smaller amplitude that affects the normal operation of precision equipment and instruments.

2.0.2 Allowable value of vibration

The maximum allowable value of vibration at the support/bearing structures to ensure normal operation of precision equipment and instruments.

2.0.3 Structural microvibration control system

Comprehensive measures taken at the building structures to reduce the effect of environment vibration to ensure normal operation of precision equipment and instruments.

2.0.4 Active vibration isolation

Isolation measures taken to reduce the effect of vibration of utility equipment to the ambient environment.

2.0.5 Passive vibration isolation

Isolation measures taken to reduce the effect of environment vibration to precision equipment and instruments.

2.0.6 Active vibration isolating device

A preset device that can obtain signal from self-feedback system and impose at real time an opposite force through vibration isolating mounting to reduce the effect of environment vibration to ensure normal operation of equipment.

2.0.7 Vibration isolator

Bearing element with the function of vibration attenuation.

2.0.8 Vibration isolation mounting

An isolation assembly composed of vibration isolators, dampers, regulating valves, controllers and signal processors.

2.0.9 Vibration isolation system

A system composed of isolated objects, cover plates, vibration isolators or vibration isolation mountings.

2.0.10 Vibration response

The displacement, velocity, acceleration of vibration as output of building structure and/or a vibration isolation system which are subject to vibration.

2.0.11 Environment vibration

Vibrations of site or building generated with the influence of internal and external vibration sources.

2.0.12 Usual environmental micro-vibration

Slight vibration of site or building with unknown vibration source.

2.0.13 Microvibration isolation wall

Walls set in buildings to reduce the effects of vibrations.

2.0.14 Waffle slab

The reinforced concrete porous floor slab cast in place on the production floor of vertical unidirectional-flow cleanroom.

2.0.15 Anti-microvibration design

Comprehensive measures taken during facility planning, structural design and isolation design for the precision equipment and instruments, to control the effects of environment vibration within allowable value of vibration.

2.0.16 Anti-microvibration table

A structural system composed of cover plates and support/bearing structures with function of vibration isolation. The support/bearing structure can be building structure or independent beams, slabs, columns and foundations. The vibration isolators or vibration isolation mountings may be installed between the cover plate and the support/bearing structure.

3 Basic requirements

3.0.1 The microvibration defined in this code shall be vibrations with amplitude equal or less than vibration limits specified in Table 3.0.1.

Table 3.0.1 Microvibration limits

Physical quantity of microvibration	Vibration displacement(μm)	Vibration velocity(μm/s)	Vibration acceleration(m/s^2)
Vibration amplitude in frequency domain	≤0.50	≤50	$\leqslant 2\times10^{-1}$
Vibration amplitude in time domain	≤10	≤1000	-

3.0.2 The survey, design, construction and installation of an anti-microvibration engineering should be in compliance with the following procedures:

1 Determine the criteria of allowable vibration for precision equipment and instruments;

2 Site survey, hydrogeology investigation and measurement of dynamic characteristics of foundations;

3 Measurement and analysis of environment vibration;

4 Comprehensive evaluation and selection of the site;

5 Discussion and determination of design concept of anti-microvibration engineering;

6 Detailed design of anti-microvibration engineering;

7 Construction and installation of anti-microvibration engineering;

8 Measurement and analysis of dynamic characteristics of structures after completion of main structure without installation of various equipment;

9 Measurement and analysis of environment vibration during trial operation of utility equipment;

10 Measurement and analysis of environment vibration during the trial production;

11 Acceptance of anti-microvibration engineering;

12 The measurement and analyses of microvibration shall meet the requirements specified in the Appendix A of this code.

3.0.3 During area and plant planning, the locations of vibration sources shall be properly arranged. Vibration with larger amplitude should be located at the boundary of zones or far away from structures with anti-microvibration requirements.

3.0.4 Vibration sources and precision equipment and instruments inside the structure shall be located together by categories, distributed in different zones, and kept away from each other.

3.0.5 In design of an anti-microvibration engineering, the following shall be included:

1 Design of anti-microvibration of building structure;

2 Design of vibration isolation of utility equipment and pipes;

3 Design of vibration isolation of precision equipment and instruments.

3.0.6 The design and constructional quality of anti-microvibration engineering must meet the criteria of allowable vibration for precision equipment and instruments.

4 Allowable value of vibration of precision instrument and equipment

4.1 General requirements

4.1.1 Determination of allowable value of vibration of precision equipment and instruments shall be in accordance with one of the following requirements:

1 Allowable value of vibration provided by the supplier;

2 Allowable value of vibration required by the process;

3 Allowable value of vibration specified in Section 4.2 of this code.

4.1.2 The determination of allowable value of vibration of precision equipment and instruments should take changes of the environment vibration and requirements of the equipment update into consideration.

4.2 Allowance value of vibration

4.2.1 Allowable value of vibration in vertical and horizontal directions in the frequency domain for precision equipment and instruments in electronic industry, nanometer laboratories and physics laboratories may be determined according to those specified in Table 4.2.1.

Table 4.2.1 Allowable value of vibration of precision equipment and instruments in electronic industry, nanometer laboratories, and physics laboratories

No.	Precision equipment and instruments	Maximum allowable vibration velocity (μm/s)	Maximum allowable vibration acceleration (m/s^2)	Corresponding frequency (Hz)
1	Nanometer research devices	0.78	–	1–100
2	Nanometer experimental devices	1.60	–	1–100
3	Long-path laser equipment, 0.1μm ultra-precision machining and test instruments	3.00	–	1–100
4	0.1μm–0.3μm ultra-precision processing and test instruments, electron beam devices, electron microscopes (transmission electron microscopes, scanning electron microscopes, and etc.)	6.00	–	1–100
5	1μm–3μm (less than 3μm) precision processing and test instruments, processing devices used for array, color film and cell in TFT-LCD and OLED, and nuclear magnetic resonance imaging devices	12.00	–	1–100
6	3μm precision machining and measurement devices, TFT-LCD backlight assembling devices, LED processing devices, an optical microscopes to 1000X	–	1.25×10^{-3}	4–8
		25.00	–	8–100
7	Contact and projection photo etching machines, thin film solar cell processing device, and optical microscope to 400X	–	2.50×10^{-3}	4–8
		50.00	–	8–100

Note: The vibration velocity and acceleration are root-mean-square of 1/3 octave.

4.2.2 Allowable value of vibration in vertical and horizontal directions in the frequency domain for precision equipment and instruments used in laboratories may be determined according to those specified in Table 4.2.2.

Table 4.2.2 Allowable value of vibration of precision equipment and instruments used in laboratories

No.	Precision equipment and instruments	Maximum allowable vibration displacement (μm)	Maximum allowable vibration velocity (μm/s)
1	Light wave interference aperture measuring instruments with resolution 0.03μm, interferometers with resolution 0.02μm, and optical tube goniometers with resolution 0.01μm	–	30
2	Measuring instruments with surface roughness of 0.025μm	–	50
3	Galvanometers, 0.2μm spectroscopes (goniometers), and stereo full-phase microscopes	–	100
4	1st class balances with precision of 1×10^{-7}	1.5	–
5	Vertical (horizontal) optical comparators and projection odometers with precision of 1μm	–	200
6	Single beam balance and 3-stagebalance with precision of 1×10^{-5}–5×10^{-7}	3.0	–
7	Contact interferometers, universal analysis microscopes with precision of 1μm	–	300
8	6-stage balances, analytical balance, gyroscope swing test benches, gyroscope deflection test benches, and gyroscope damping test benches	4.8	–
9	Horizontal photometers, Abbe comparators, potentiometers, and universal length measuring instruments	–	500
10	Desktop light-spot reflecting galvanometers, hardness testers, chromatographs, and humidity controllers	10.0	–
11	Horizontal optical instruments, torsion spring comparators, and direct reading spectrometers	–	700
12	Oscillograph line detectors, and dynamic balancing machines	–	1000

Notes: 1 The vibration displacement and velocity are peak values;

2 If the vibration velocity and acceleration of precision equipment and instruments are listed in the table, both of the values shall be satisfied.

4.2.3 Allowable value of vibration in vertical and horizontal directions in the frequency domain for anechoic and semi-anechoic rooms may be determined according to those specified in Table 4.2.3.

Table 4.2.3 Allowable value of vibration for anechoic and semi-anechoic rooms

Background noise dB(A)	Accelerations corresponding to different frequencies(m/s^2)				
	31.5Hz	63.0Hz	125.0Hz	250.0Hz	500.0Hz
20	6.5×10^{-3}	3.0×10^{-3}	1.8×10^{-3}	1.5×10^{-3}	1.5×10^{-3}
25	1.1×10^{-2}	5.0×10^{-3}	3.0×10^{-3}	2.5×10^{-3}	2.5×10^{-3}
30	2.0×10^{-2}	8.5×10^{-3}	5.5×10^{-3}	4.5×10^{-3}	4.5×10^{-3}
35	3.5×10^{-2}	1.5×10^{-2}	1.0×10^{-2}	8.5×10^{-3}	8.5×10^{-3}
40	6.0×10^{-2}	2.5×10^{-2}	1.7×10^{-2}	1.5×10^{-2}	1.5×10^{-2}
45	1.0×10^{-1}	4.5×10^{-2}	3.0×10^{-2}	2.5×10^{-2}	2.5×10^{-2}
50	1.0×10^{-1}	8.5×10^{-2}	5.0×10^{-2}	4.5×10^{-2}	4.5×10^{-2}

Note: The vibration acceleration is root-mean-square of octave.

4.2.4 Allowable value of vibration in vertical and horizontal directions in the frequency domain for anechoic pools may be determined according to those specified in Table 4.2.4.

Table 4.2.4 Allowable value of vibration for anechoic pool

Place of vibration control	Octave vibration acceleration(m/s^2)	Corresponding frequency(Hz)
Sidewalls, baseboards	1.5×10^{-5}	400–1000

Note: The vibration acceleration is root-mean-square.

5 Planning and design

5.1 General requirements

5.1.1 During area planning and plant layout in electronic industry, area with strong vibration sources, noise, blown sand, electromagnetic radiation, and harmful gases must not be considered.

5.1.2 Site selection should be in accordance with the following requirements:

1 The site should be in areas with harder foundation soil or shallower bedrock, instead of adverse areas with defective geologies, such as soft soil or fill;

2 Rivers, lakes, beaches, and perennial frozen areas should be avoided;

3 The site should be in areas with seismic fortification intensity no more than 8 degrees, and unfavorable areas such as seismic active fault zones. The liquefied sand layers should be avoided. Those stipulated in the current national standard GB 50011 *Code for Seismic Design of Buildings* shall be also met in site selection;

4 When the areas with adverse conditions similar to those mentioned above cannot be avoided, relevant treatment shall be taken.

5.1.3 The site selection shall be determined through discussion, comparison, and full evaluations based on the environment microvibration measurements and the natural conditions of the site; In case, environment vibration measurements are not possible, the anti-microvibration distance from vibration source may be determined by section 5.2 of this code.

5.2 Anti-microvibration distance

5.2.1 The anti-vibration distance of various vibration sources in different soil may be calculated according to the following formula:

$$L = K_1 K_2 L_0 \tag{5.2.1}$$

Where, L—anti-microvibration distance without any anti-microvibration measures (m);

K_1—adjustment coefficient of different soil, according to Table 5.2.1-2;

K_2—adjustment coefficient of different types of vehicles, according to Table 5.2.1-3, for other vibration sources, $K_2=1$;

L_0—anti-microvibration distance for clay (m), according to Table 5.2.1-1.

Table 5.2.1-1 Anti-microvibration distance L_0(m)

Type of vibration sources \ Vibration velocity limit(mm/s)			0.003	0.005	0.01	0.02	0.03	0.05	0.10	0.20	0.3	0.5
Steady state	Air compressors	Medium	250	150	100	65	52	38	26	17	14	10
	Chiller	Large	100	82	64	50	42	35	28	21	18	15
		Medium	80	65	50	37	32	26	19	15	12	10
		Small	50	40	30	22	19	55	11	8	7	6

Table 5.2.1-1(continued)

Type of vibration sources \ Vibration velocity limit(mm/s)			0.003	0.005	0.01	0.02	0.03	0.05	0.10	0.20	0.3	0.5
Steady state	Medium fans		55–65	46–56	33–44	28–34	25–30	20–25	16–20	12–15	9–11	7–9
	Grinders		35	29	22	17	15	12	10	7.5	6.5	5
	Water pumps		30	25	18	14	12	10	6.5	5.5	5	4
Transient state	Forging hammers	1t	900	700	500	360	300	230	160	120	95	65
		0.4t–0.75t	700	520	360	250	200	150	100	74	60	46
		≤0.25t	500	380	270	180	150	115	80	55	46	35
	Punches	315t	700	550	400	280	210	160	130	100	82	65
		160t	500	380	270	190	160	120	88	62	50	40
		63t	300	220	160	110	88	65	46	32	26	20
		50t	240	180	130	88	70	52	36	25	20	15
		30t	220	160	110	74	60	44	30	20	16	12
		≤15t	200	150	100	65	52	38	26	18	14	10
Random state	Trains	Railway	2000	1600	1150	850	700	560	420	300	250	200
		Urban subway	800	560	360	260	175	102	80	50	38	28
	Vehicles	Highway	500	380	250	165	130	100	65	43	34	30
		Factory road (soft ground)	180	130	80	52	40	26	18	11	8.5	6
		Factory road (rigid ground)	250	170	110	68	50	38	24	15	11	8

Notes: 1 Allowable value of vibration in the table are values in time domain;

2 The intermediate vibration velocity limit may be determined by linear interpolation from values listed in the table;

3 Anti-microvibration distance of other utility equipment should be determined by measurement.

Table 5.2.1-2 Adjustment coefficient K_1 for different ground and foundation

Soil	Mucky soil	Clay	Hard soil	Pile foundation
K_1	2–3	1	0.25–0.35	0.8

Note: The smaller value shall be taken when the hard soil is bedrock.

Table 5.2.1-3 Adjustment coefficient of different types of vehicles K_2

Vehicles type	Vehicles ≥8t	Vehicles 4t	Tourist bus, coaches	Medium-sized trucks	Vans	Small-sized trucks	Cars
K_2	1.3	1	0.8	0.7	0.5	0.4	0.3

5.2.2 When isolation measures are taken for vibration sources in Table 5.2.1-1 of this code, anti-microvibration distance after vibration isolation shall be determined by measurement.

5.2.3 The anti-microvibration distance should be determined by the maximum vibration response according to comprehensive vibration superposition for buildings with anti-microvibration requirements, combining different vibration sources internal and external of the planning and plant area. The superposition calculation of vibration responses under multiple vibration sources may be calculated according to Appendix B of this code.

5.3 Plant layout

5.3.1 Layout of buildings with vibration sources or precision equipment and instruments inside the plant area shall be in accordance with the following requirements:

1 Forging and press workshop shall be placed at the edge of the plant area, and kept away from buildings with anti-microvibration requirements;

2 Air compressor, chiller, water pump and other utility station buildings and other vibration sources should be separately arranged and located;

3 Precision equipment and instruments shall be located in areas with minimum vibration influence.

5.3.2 The road layout inside and outside the plant area shall be in accordance with the following requirements:

1 Buildings with anti-microvibration requirements shall be kept away from the main roads of the plant area, railways, highways, and urban rail transit lines;

2 The bed of road around buildings with anti-microvibration requirements shall be reinforced, and soft pavement should be selected;

3 The load, speed and traffic time of vehicles should be limited for the road around buildings with anti-microvibration requirements.

5.3.3 The evergreen shrubs and turf should be planted around the buildings with anti-microvibration requirements in the plant area, except for arbors.

6 Anti-microvibration of building structures

6.1 General requirements

6.1.1 The following comprehensive measures shall be taken in design of anti-microvibration for structures:

1 Anti-microvibration measure for building foundation;

2 Anti-microvibration measure for ground structure;

3 Anti-microvibration measure forma in structure;

4 Anti-microvibration measure for independent foundation of precision equipment and instruments.

6.1.2 The following data shall be required in design of anti-microvibration for structures:

1 Allowable value of vibration of precision equipment and instruments;

2 Survey report of project geology and hydrogeology;

3 Measurement report on dynamic properties of foundation. In case of no data available, values may be taken from relevant provisions in GB 50040 *Code for Design of Dynamic Machine Foundation*.

4 Measurement and analysis report of environment vibration of site.

6.1.3 The following data should be available in design of anti-microvibration for structures:

1 The process layout, boundary dimensions, weight and operation mode of precision equipment and instruments inside the building;

2 The position, boundary dimensions, weight, rotation speed and operation mode of utility equipment inside the building;

3 The spatial position, weight per unit length and conveying medium of pipes inside the building.

6.1.4 Layout of equipment in the building shall be in accordance with the following requirements:

1 When precision equipment and instruments and utility equipment are located closer to each other, they should be separated by vibration isolation joints;

2 When precision equipment and instruments are arranged on the floor, utility equipment shall be located in the bottom floor or side spans of the floor, and vibration isolation joints shall be placed in the floor for separation from areas where precision equipment and instruments are located;

3 Precision equipment and instruments should not be located in the areas that are within the vibration range of elevator;

4 When precision equipment and instruments are located in the floor, their locations should be at or near beams, walls, columns or other parts which have greater structural stiffness.

6.1.5 Hoisting equipment should not be installed in multi-storey buildings. When setting up hoisting equipment, cantilever hoisting equipment or other transportation means with less vibration impact should be adopted.

6.1.6 Vibration isolation measures shall be taken when utility equipment and vibration-generating pipes are inside anti-microvibration zones of buildings.

6.1.7 Low velocity air supply shall be adopted in the building, and the rate of air density change should be controlled within 10%. Vibration isolation measures shall be taken when high efficiency fan filter units(FFU) are installed.

6.1.8 The door in the anti-microvibration area shall have flexible buffer device.

6.2 Anti-microvibration measures

6.2.1 Anti-microvibration design of building foundation shall be in accordance with the following requirements:

1 In areas with seismic fortification intensity of 7 and 8 degrees, pile foundation or artificially composite foundation shall be adopted, where there are soft clay layers within the bearing stratum of building foundation, which have characteristic value of pressure bearing capacity less than 80kPa and 100kPa, respectively. When composite foundation is adopted, load test and foundation deformation calculation shall be carried out according to the relevant provisions of current national standards GB 50007 *Code for Design of Building Foundation* and JGJ 79 *Technical Code for Ground Treatment of Buildings*;

2 The foundation of same structural unit of anti-microvibration plant should not be buried on different foundation soil.

6.2.2 The anti-microvibration design of ground structure or foundation shall be in accordance with the following requirements:

1 The thick floor reinforced concrete ground shall be set up based on requirements of anti-microvibration for workshops of frontend of the integrated circuit manufacturing plant, the LCD manufacturing plant, the nanotechnology building, and the laboratory. When natural foundation is used, the thickness of the ground structure should be equal to or more than 500mm, and the compaction coefficient of the foundation soil must be equal to or more than 0.95. When pile foundation is used to support the ground, the thickness of the ground structure should be equal to or more than 400mm, while for soft soil area, should be equal to or more than 500mm; For less consolidated soil, measures should be taken to prevent the soil between piles from separation with the bottom of the ground structure;

2 When the ground is of exceptionally long concrete structure, expansion joints should not be set, and jointless measures may be used.

6.2.3 Anti-microvibration design of structures shall be in accordance with the following requirements:

1 Small-span column grid should be used in the workshops of frontend of integrated circuit manufacturing plants, liquid crystal display device manufacturing plants, photovoltaic solar energy manufacturing plants, nanotechnology buildings, and various laboratories. The reinforced concrete structures should be used in the platform of process equipment layer. Isolation joints should be set between the platform and surrounding structures.

2 The design of anti-microvibration process platform shall be in accordance with the following requirements:

1) The size of the column grid under the platform shall take 0.6m as modulus, the span should be equal to or less than 6m;

2) Reinforced concrete beam-slab or cross-beam floor structure cast in place should be used on the platform, or steel frame composite floor structure may be used;

3) The minimum dimensions of beam, floor, column of the reinforced concrete platform cast in place should be in accordance with those specified in Table 6.2.3-1.

Table 6.2.3-1 Minimum cross-section of beam, floor and column

Column section (mm)	Height-span ratio of girder	Slab with beam		Slab with cross-beam	
		Height-span ratio of slab	Height-span ratio of secondary beam	Slab thickness (mm)	Height-span ratio of secondary beam
600×600	1/8	1/20	1/12	150	1/15

4) When the distance between secondary beams of waffle slab cast in place in anti-microvibration process equipment platform is 1.2m, the minimum dimensions of cross-section should be in accordance with those specified in Table 6.2.3-2;

Table 6.2.3-2 Minimum cross-section of waffle slab

Height-span ratio of secondary beam	Height-span ratio of girder	Slab thickness(mm)	Hole diameter in floor d(mm)
1/10	1/8	180	300

5) When steel frame-composite slab structure is used in anti-microvibration process equipment platform, the distance between secondary beams should be equal to or less than 3.2m, the minimum dimensions of sections of steel beams and composite slabs should be in accordance with those specified in Table 6.2.3-3;

Table 6.2.3-3 Minimum cross-section of steel beam and composite floor

Height-span ratio of secondary beam	Height-span ratio of girder	Slab thickness(mm)
1/18	1/12	250

6) The opening ratio of the waffle slab of process equipment platform with anti-microvibration performance shall meet the requirements of clean design, and should be equal to or less than 30%.

3 For exceptionally long concrete building, expansion joints should not be set, and jointless design for exceptionally long concrete structure shall be adopted, and measures to reduce temperature expansion stress shall be taken.

4 Depending on the needs of anti-microvibration, reinforced concrete anti-microvibration walls may be set between columns under the platform. The walls should be arranged symmetrically in both horizontal and vertical directions, and the thickness should be equal to or more than 250mm, and there should be no holes in the wall.

5 When a joint is set between the middle column and the process equipment floor platform in the multi-span roof structure, the joint width shall be equal to or more than 50mm in non-seismic areas, and shall be equal to or more than 100mm in seismic areas. The relevant provisions of seismic joint in the current national standard GB 50011 *Code for Seismic Design of Buildings* shall be followed.

6.2.4 The design of independent foundation for precision equipment and instruments shall be in accordance with the following requirements:

1 Foundation shall be placed on hard soil or bedrock for precision equipment and instruments set on the ground. Under other geological conditions, pile foundation or artificially composite foundation shall be adopted;

2 When precision equipment and instruments are sensitive to the mid-to-low frequency vibration, vibration isolation trench may not be placed around foundation;

3 If frame support is used for the base of precision equipment and instruments, reinforced

concrete frame should be adopted, and steel reinforced concrete structures should be adopted for cover plates, around which isolation joints shall be set;

4 Anti-microvibration tables should be used for precision equipment and instruments located on process equipment floor. Steel reinforced concrete structures should be adopted for cover plates, and the thickness of cover plates should be equal to or more than 200mm.

6.3 Microvibration checking calculation

6.3.1 Microvibration calculation shall be in accordance with the following requirements:

1 Anti-microvibration calculation should be conducted for the following elements of workshops and laboratories with anti-microvibration requirements:

1)Ground structure;

2)Process floor;

3)Independent foundation.

2 Microvibration calculation shall be conducted in several phases according to the following vibration effects:

1)Environment vibration;

2)Vibration of utility and process equipment.

3 Microvibration calculation shall be in accordance with the following requirements:

1)Overall solid modeling of the structure shall be used for microvibration calculation.

2)The dynamic property factors of natural, pile and artificially composite foundations shall be determined by measurement on site. When this is not possible, values may be adopted according to the relevant provisions of the current national standard GB 50040 *Code for Design of Dynamic Machine Foundation*, and damping ratio may be determined according to the following 4 in this item.

3)The effect of backfilling soil around ground structure to the foundation stiffness may follow relevant provisions in current national standard GB 50040 *Code for Design of Dynamic Machine Foundation*.

4)Damping ratio should be 0.15–0.35 for foundation soil. Damping ratio should be 0.05 for reinforced concrete structure. Damping ratio should be 0.02 for steel frame. Damping ratio should be 0.035 for steel and concrete composite structure.

5)Soil within the depth range of foundation influence shall be used in depth calculation.

6)Calculate the influence of live loads.

7)Conduct modeling and response calculations of the structure. For effective vibration modes quantity in modeling analysis, the value should be taken based on equal to or more than 95% as mass involvement coefficient of structure overall vibration modes.

8)The worst record of vibration shall be used as input load for calculation of environment vibration influence. The sampling time should be equal to or more than 60 seconds.

4 The establishment of analysis model shall be in accordance with the following requirements:

1)Clarify anti-microvibration design plan, and simplify calculation model of ground and structures of process floor. When the process equipment floor is connected with the main building structure, structural calculation model shall include the main structure;

2)Set geometric factors according to design plan;

3)Select reasonable physical factors;

4)Determine viscoelastic boundary constraints according to project geological survey report.

5 The response value of vibration influence calculation shall be in accordance with the following requirements:

$$R \leqslant [R] \tag{6.3.1}$$

Where, R—vibration response value of center point or feature point of the structure;

$[R]$—allowable value of vibration of precision equipment and instruments.

6.3.2 Microvibration under the influence of environment vibration shall be calculated according to the following formulas:

$$R_{hV} \leqslant K_V [R_V] \tag{6.3.2-1}$$

$$R_{hH} \leqslant K_H [R_H] \tag{6.3.2-2}$$

Where, R_{hV}—vertical vibration response of the central point of the structure;

R_{hH}—horizontal vibration response of the central point of the structure;

K_V—vertical dynamic influence factor. K_V=0.4–0.6. This factor is related to the quantity and layout of utility equipment. When quantity of equipment is large or the distance from feature point is short, the small value for K_V shall be taken. Otherwise, large value shall be taken;

K_H—horizontal dynamic influence factor. K_H =0.3–0.5. This factor is related to the quantity and layout of utility equipment. When the quantity of equipment is large or the distance from feature point is short, the small value for K_H shall be taken. Otherwise, large value shall be taken;

$[R_V]$—vertical allowable value of vibration of precision equipment and instruments;

$[R_H]$—horizontal allowable value of vibration of precision equipment and instruments.

6.3.3 Calculation of microvibration under the influence of utility equipment and process equipment shall be in accordance with the following requirements:

1 Feature points shall be selected from the established actual model, and its dynamic response spectrum R_d shall be calculated under the unit load 1kN;

2 The vibration response of feature points shall be calculated according to the following formulas:

$$R_V = \eta \alpha_v R_{dV} \tag{6.3.3-1}$$

$$R_H = \eta \alpha_H R_{dH} \tag{6.3.3-2}$$

$$\alpha_V = \frac{R_{VS}}{R_{Vd}} \tag{6.3.3-3}$$

$$\alpha_H = \frac{R_{HS}}{R_{Hd}} \tag{6.3.3-4}$$

Where, R_V—vertical vibration response of structure feature point;

R_H—horizontal vibration response of structure feature point;

α_V—vertical dynamic response factor of feature points in finished projects of same type;

R_{VS}—vertical vibration response curve of feature points obtained by frequency domain analysis of feature points vibration report finished projects of same type;

R_{Vd}—establish finite element solid model of same type of finished projects, exert a unit load P= 1kN vertically on the feature point, and calculate dynamic response curve;

α_H—horizontal dynamic response factor of feature points in finished projects of same type;

R_{HS}—horizontal vibration response curve of feature points obtained by frequency domain analysis of feature points vibration report of finished projects of same type;

R_{Hd}—establish finite element solid model of finished projects of same type, exert a unit load P= 1kN horizontally on the feature point, and calculate dynamic response curve;

η—the similarity ratio coefficient of finished project to the one under construction of same type may take 0.9–1.2;

R_{dV}—vertical vibration response of structure feature point under the unit load 1kN;

R_{dH}—horizontal vibration response of structure feature point under the unit load 1kN.

6.3.4 The measurement and evaluation of vibration of different phases of anti-microvibration engineering shall be in accordance with the following requirements:

1 During the site environment vibration measurement, the data of the proposed site affected by the environment vibration shall be obtained through measurement, and shall be used as the input load to calculate for the preliminary anti-microvibration design scheme;

2 During measurement and evaluation of the completed building structure, the main structural anti-microvibration engineering shall be evaluated through vibration measurement on main building structure, which shall be compared with the calculation result to verify its effectiveness and to provide basis for overall vibration isolation design of utility and process equipment;

3 During measurement and evaluation of the vibration of utility and process equipment, the finally built structural anti-microvibration engineering shall be evaluated through vibration measurement on structures when utility and process equipment are in operation, the results of which shall be compared with the calculation result to verify its effectiveness and to provide basis for local vibration isolation design of utility and process equipment.

7 Isolation design

7.1 General requirements

7.1.1 Product with light vibration effect shall be selected as utility equipment, product with medium or high rotating speed shall be selected as rotating equipment.

7.1.2 When precision equipment and instruments are affected by vibration from utility equipment, isolation measures shall be taken.

7.1.3 If requirements aren't satisfied when anti-microvibration measures for building structures and isolation measures for utility equipment have been taken, isolation measures for precision equipment and instruments shall be taken.

7.1.4 In addition to the requirements stipulated in this code, the isolation design shall meet the relevant requirements in the current national standard GB 50463 *Code for Design of Vibration Isolation*.

7.1.5 For selection of commercial vibration isolator, the following information shall be available:

1 Dimensions, weight, and installation requirements;

2 Bearing capacity range;

3 Stiffness value and variation range;

4 Damping ratio and variation range;

5 Load-compression-frequency relation chart;

6 Operation environmental conditions.

7.1.6 In selection of air spring vibration isolation device, in addition to the requirements of article 7.1.5 in this code, the following information shall be required:

1 Range of operation pressure and maximum allowable pressure;

2 Operation height;

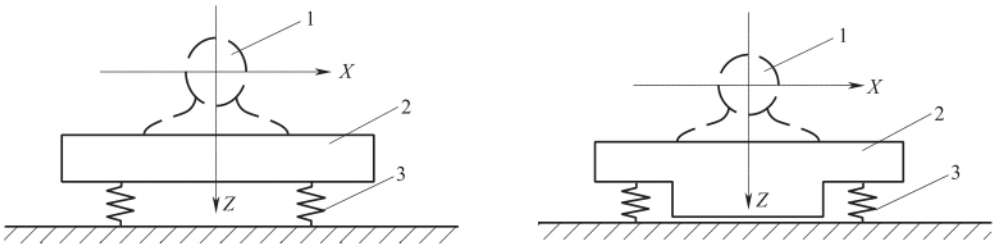
3 Inflation time;

4 Automatic leveling time and accuracy.

7.1.7 Vibration isolation system shall not be rigidly connected with peripheral structures.

7.2 Active isolation

7.2.1 The type of support isolation should be adopted for utility equipment (Figure 7.2.1).



(a) Common support structure　　(b) Special support structure

Figure 7.2.1 Isolation scheme

1–Utility equipment; 2–Cover plate; 3–Isolator

7.2.2 Isolation for utility equipment shall be in accordance with the following requirements:

1 For utility equipment installed on the ground or in the basement, reinforced concrete or steel cover plates may be used.

2 For utility equipment installed in the floor or on the roof, steel cover plates should be used. For utility equipment installed together on the floor, vibration isolation of floating slab should be used.

3 For utility equipment related to acoustic laboratories, reinforced concrete cover plates should be used, and the mass ratio between the cover plate and equipment should be more than 3.

7.2.3 Pipe isolation should be in accordance with the following requirements:

1 Suspension isolation system should be adopted for horizontal pipes, and support isolation system should be adopted for vertical pipes(Figure 7.2.3-1);

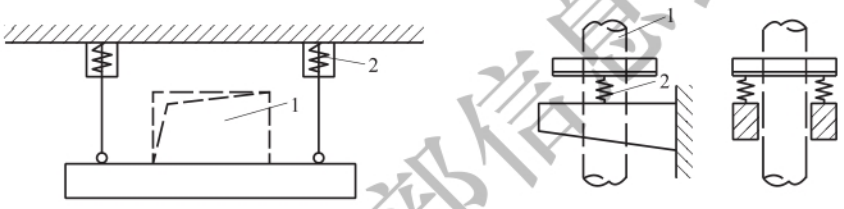


Figure 7.2.3-1 Isolation scheme

1-Pipe ;2-Isolator

2 Support isolation system should be adopted for pipes through walls (Figure 7.2.3-2);

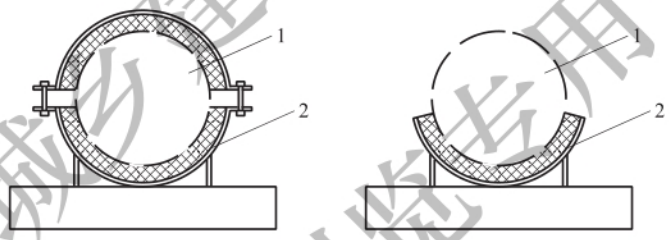


Figure 7.2.3-2 Support isolation scheme

1-Pipe;2-Isolation bracket

3 Flexible connections shall be adopted between pipes and utility equipment;

4 Isolators shall be arranged according to isolation requirements, pipe loads, and regulations on relevant specialties.

7.2.4 The selection of isolators should be in accordance with the following requirements:

1 Rubber vibration isolation mat, rubber vibration isolator, metal damping spring vibration isolator, and/or air spring isolator should be used for indoor utility equipment and pipes;

2 Metal damping spring vibration isolator should be used for outdoor utility equipment and pipe.

7.2.5 Isolation performance test report shall be provided for utility equipment with isolators.

7.2.6 When the one-stage isolation scheme of utility equipment can't meet the requirements, two-stage or multistage isolation system may be used.

7.2.7 Vibration isolation transfer rate of utility equipment should not be more than 0.1.

7.3 Passive isolation

7.3.1 Isolation design of precision equipment and instruments shall be determined according to allowable value of vibration, operation features, support conditions and installation requirements of the precision equipment and instruments. Isolation calculation shall be performed to select isolator or isolation device.

7.3.2 The isolation types of precision equipment and instruments should be in accordance with the following requirements:

1 For support isolation, the isolator is set under the isolation plate, and combines with the isolation plate to form the isolation system (Figure 7.3.2-1);

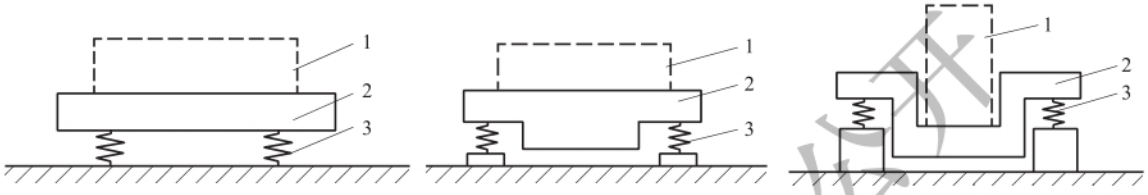


Figure 7.3.2-1 Support isolation scheme

1-Precision equipment and instruments; 2-Isolation plate; 3-Isolator

2 For suspension isolation, the isolator is connected in series with rigid suspenders and combines with the isolation plate to form the isolation system(Figure 7.3.2-2).

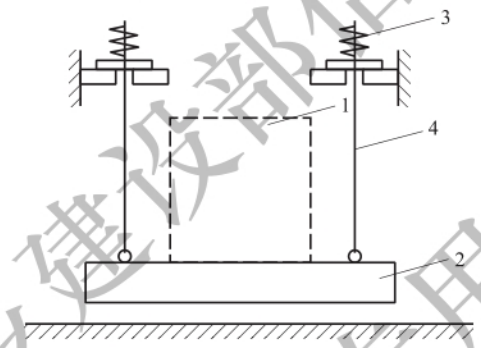


Figure 7.3.2-2 Suspension isolation scheme

1-Precision equipment and instruments; 2-Isolation plate; 3-Isolator; 4-Rigid suspender

7.3.3 For precision equipment and instruments whose weight and center of gravity position are changing during operation, isolation device with tilt correction mechanism shall be selected.

7.3.4 The following shall be included in isolation calculation:

1 Natural frequency of vibration isolation system;

2 Vibration response of isolation system under external vibration source;

3 Vibration response of isolation system under internal vibration source.

7.3.5 Calculation of large or exceptionally large isolation system should include the elastic deformation effect of cover plates.

7.3.6 Vibration calculation shall not include the isolation effect of the built-in isolator in precision equipment and instruments.

7.3.7 If passive isolation control measures cannot satisfy the requirements, isolation device with active control shall be used.

7.3.8 Damping ratio of the vibration isolation system should be equal to or more than 0.08.

8 Acceptance of constructional quality of anti-microvibration engineering

8.1 General requirements

8.1.1 Quality acceptance of anti-microvibration engineering shall be undertaken all together by contractor, designer, and supervisor, which shall be organized by the owner. Once passed, procedures for completion and acceptance of the project shall be gone through.

8.1.2 The construction of anti-microvibration engineering shall be conducted according to approved design documentation. If there is a change in design, it shall be confirmed by the original design company and be approved by the owner.

8.1.3 During anti-microvibration engineering construction, the specialized personnel and technicians for commissioning of anti-microvibration equipment shall have certificates according to relevant requirements.

8.1.4 Various tools and instruments used during construction of anti-microvibration engineering shall be calibrated and within their validity.

8.1.5 Major equipment, materials, finished products and semi-finished products shall be inspected for site entry. In addition to the requirements stipulated in the current national standards, the following requirements shall be followed:

1 Major equipment, materials, finished products and semi-finished products shall have quality certificates;

2 Major equipment, materials, finished products and semi-finished products shall have inspection record for entry;

3 In case of any quality objection, test shall be conducted by the organization with relevant qualification. After the qualified test report is issued, it may be used in the engineering;

4 For quality acceptance of imported anti-microvibration devices, tools and materials, commodity inspection certificate and quality certificate of Chinese version, as well as relevant technical documents, such as technical specifications and installation manual, shall be provided, in addition to requirements of Item 1–3 of this code.

8.1.6 In addition to the requirements in this code, the constructional quality acceptance of the anti-microvibration engineering shall meet the requirements in the current national standard GB 50300 *Unified Standard for Constructional Quality Acceptance of Building Engineering*.

8.1.7 The material, model number, specifications, and quantity of the isolators and isolation devices used in isolation engineering of anti-microvibration tables, utility equipment and pipes shall be in accordance with the following requirements:

1 The technical documents, such as qualification certificate, performance test report, and installation and operation instructions, shall be provided;

2 The packing and appearance are complete, without defect and crack, and the coating is complete.

8.2 Acceptance of constructional quality of foundation treatment

8.2.1 The quality acceptance criteria of foundation treatment for anti-microvibration engineering shall be in accordance with those specified in Table 8.2.1.

Table 8.2.1 Constructional quality acceptance criteria of foundation treatment for anti-microvibration engineering

Name	No.	Inspection item	Maximum allowable error or value	Inspection method
Main control items	1	Bearing capacity and deflection of foundation	According to requirements of design	According to the method specified in the current national standard GB 50202 *Code for Acceptance of Construction Quality of Building Foundation*
	2	Dynamic characteristics parameter of foundation	According to requirements of design	

8.2.2 In addition to the requirements specified in this code, methods used in foundation treatment of the anti-microvibration engineering shall meet the relevant requirements specified in the current national standard GB 50202 *Code for Acceptance of Construction Quality of Building Foundation*.

8.3 Acceptance of constructional quality of cubage concrete anti-microvibration foundation

8.3.1 The quality acceptance of foundation shall include concrete foundations of utility equipment and precision equipment and instruments.

8.3.2 Constructional quality acceptance criteria of concrete block foundation with anti-microvibration performance shall be in accordance with those specified in Table 8.3.2.

Table 8.3.2 Quality acceptance criteria of concrete block foundation for anti-microvibration

Name	No.	Type of equipment	Inspection item	Maximum allowable error or tolerance	Inspection method
Main control items	1	Utility equipment	Load capacity of foundation	According to requirements of design	According to the method specified in the current national standard GB 50202 *Code for Acceptance of Construction Quality of Building Foundation*
	2		Vibration value of periphery outside the foundation	According to requirements of design	According to the method specified in Appendix A of this code
	3	Precision equipment and instruments	Load capacity of foundation	According to requirements of design	According to the method specified in the current national standard GB 50202 *Code for Acceptance of Construction Quality of Building Foundation*
	4		Vibration value of top surface of foundation	According to requirements of design	According to the method specified in Appendix A of this code
	5		Evenness of top surface of foundation	According to requirements of design	Measure with straightedge

8.4 Acceptance of constructional quality of structure of anti-microvibration engineering

8.4.1 Quality acceptance of structures in anti-microvibration engineering shall include quality acceptance of structures, such as foundation, beam, board, column in workshops with precision

equipment which have anti-microvibration requirements.

8.4.2 Quality acceptance criteria of anti-microvibration structures shall be in accordance with those specified in Table 8.4.2.

Table 8.4.2 Quality acceptance criteria in anti-microvibration structures

Name	No.	Inspection item	Maximum allowable error or tolerance	Inspection method
Main control items	1	Vibration value of structures in precision equipment's location	According to requirements of design	According to the method specified in Appendix A of this code
	2	Structural dynamic characteristic parameter	According to requirements of design	

8.5 Acceptance of constructional quality of isolation engineering of precision instrument and equipment

8.5.1 Quality acceptance of isolation facilities shall include constructional quality of anti-microvibration tables, air spring vibration isolation devices and active control vibration isolation devices.

8.5.2 Constructional quality of anti-microvibration tables of precision equipment in clean room shall be in accordance with the following requirements:

1 Anti-microvibration tables shall be installed with consideration of construction allowance of workshop structure;

2 Isolation joints shall be set around the anti-microvibration table, and the width of joint should be 10mm–15mm;

3 When isolators is set under the cover plate of anti-microvibration table, the compression of isolator after equipment's installation shall be calculated and quantified. The height of top surface of the cover plate after installation shall meet the requirements of equipment operation;

4 If no isolators under the cover plate of the anti-microvibration table are set, the cover plate shall be rigidly connected to the support system.

8.5.3 Constructional quality acceptance criteria of anti-microvibration tables shall be in accordance with those specified in Table 8.5.3.

Table 8.5.3 Quality acceptance criteria of anti-microvibration tables

Name	No.	Inspection item	Maximum allowable deviation or tolerance	Inspection method
Main control items	1	Load capacity of the table	According to the requirements of design	Load test on site
	2	Vibration value of top surface of the table	According to the requirements of design	According to the method specified in Appendix A of this code
	3	Smoothness of top surface of the table	1/1000	By straightedge
	4	Height of top surface	±2mm	Measure with leveling instruments and high precision tower scale

8.5.4 Quality acceptance criteria of air spring vibration isolation device shall be in accordance with those specified in Table 8.5.4.

Table 8.5.4 Quality acceptance criteria of air spring vibration isolation device

Name	No.	Inspection item		Maximum allowable error or tolerance	Inspection method
Main control items	1	Load capacity of air spring vibration isolation devices		According to the requirements of design	Conversion according to pressure value displayed in real time
	2	Natural vibration frequency of air spring vibration isolation devices		According to the requirements of design	According to the method specified in Appendix A of this code
	3	Vibration value of top surface of cover plates		According to the requirements of design	
	4	Smoothness of top surface of cover plates		1/1000	By straightedge
	5	Height of top surface of cover plates		±2mm	Measure with leveling instruments and high precision tower scale
	6	Height control valve	Leveling accuracy	0.05mm/m	
	7		Leveling time	Less than 15s	Check with stopwatch
	8	Air spring vibration isolators	Appearance	Flatness and smoothness of appearance	Observation
	9		Base, cover and support	No gap among the base, cover and support	
	10		Leakage	Pressure drop no more than 0.02MPa in 24h	Measurement by pressure gauge
	11		Height difference of adjacent isolators	±1mm	Measure with leveling instruments and high precision tower scale
	12	Gas pipelines	Joint tightness	No leakage	Leak test by soap liquid
	13		Pipe laying and fixing	Reliable fixation	Observation
	14	Air supplied	Pressure	Pressure more than 0.2MPa operation	Measure with pressure gauge
	15		Cleanliness	Not less than environmental requirements	Test with particle counter

8.5.5 Quality acceptance criteria of active control isolation devices shall be in accordance with those specified in Table 8.5.5.

Table 8.5.5 Quality acceptance criteria of active control isolation devices

Name	No.	Inspection item	Maximum allowable deviation or tolerance	Inspection method
Main control items	1	Load capacity of active control isolation devices	According to the requirements of design	Conversion according to pressure value displayed in the real time
	2	Vibration value of top surface of the cover plate for active control isolation devices	According to the requirements of design	According to the method specified in Appendix A of this code
	3	Vibration attenuation curve of active control isolation system	According to the requirements of design	

Table 8.5.5(continued)

Name	No.	Inspection item		Maximum allowable deviation or tolerance	Inspection method
Main control items	4	Evenness of top surface of cover plates		1/1000	By straightedge
	5	Height of top surface of cover plates		±2mm	Measure with leveling instruments and high precision tower scale
	6	Location of cover plates		±5mm	Measure with steel ruler
	7	Control unit	Leveling accuracy	0.05mm/m	Measure with leveling instruments and high precision tower scale
	8		Leveling time	Less than 5s	Check with stopwatch
	9	Active isolation device	Appearance	Flatness and smoothness of appearance	Observation
	10		Base,cover and support	No gap among the base,top and support	
	11		Installation direction	Design requirements	
	12		Height difference of adjacent vibration isolators	±1mm	Measure with leveling instruments and high precision tower scale
	13	Gas Pipelines	Joint tightness	No leakage	Leak test by soap liquid
	14		Pipe laying and fixing	Reliable fixation	Observation
	15	Air source	Pressure	0.2MPa more than operation pressure	Measuring with pressure gauge
	16		Cleanliness	Not less than environmental requirements	Test with particle counter

Note: The installation accuracy of active isolation devices shall meet specific requirements written in the technical manual provided by supplier of active control isolation devices, and shall be equal to or more than the requirements of this code.

8.6 Acceptance of constructional quality of isolation engineering of power equipment and pipe

8.6.1 Constructional quality acceptance of isolation facility of utility equipment should include the constructional quality of floating slab and isolation foundation of utility equipment.

8.6.2 Quality test criteria of utility equipment isolation facility shall be in accordance with those specified in Table 8.6.2.

Table 8.6.2 Quality acceptance criteria of utility equipment isolation facility

Name	No.	Test item		Maximum allowable error or tolerance	Test method
Main control items	1	Vibration value of the top of floating slab		According to the requirements of design	According to the method specified in Appendix A of this code
	2	Vibration value of support structure under floating slab		According to the requirements of design	
	3	Vibration value of supporting structure for vibration isolation foundation of utility equipments		According to the requirements of design	
	4	Rubber isolators	Location	±5mm	Measure with steel ruler
	5		Height difference of adjacent isolators	±1mm	Measure with leveling instruments and high precision tower scale
	6	Metal spring isolators	Location	±5mm	Measure with steel ruler
	7		Height difference of adjacent isolators	±2mm	Measure with leveling instruments and high precision tower scale
	8	Steel frame	Surface evenness	±3mm	Measurement with 2m guiding rule and wedge feeler
	9		Location	±5mm	Measure with steel ruler

8.6.3 Quality test criteria of pipe isolation facility of utility equipment shall meet the requirements of Table 8.6.3.

Table 8.6.3 Quality test criteria for pipe isolation facility

Name	No.	Test item		Allowable deviation or tolerance	Test method
Main control items	1	Vibration value of pipe support structure		According to the requirements of design	According to the method specified in Appendix A of this code
General items	1	Vibration isolation support and suspension rod	Load	According to the requirements of design	Measure with steel ruler
	2		Deflection	According to the requirements of design	According to the deflection calculation
	3		Location	±20mm	Measure with steel ruler

8.7 Acceptance of constructional quality of anti-microvibration engineering

8.7.1 The quality acceptance of the anti-microvibration engineering shall be in accordance with the following requirements:

1 Appearance and performance of the anti-microvibration engineering shall be checked 100% and shall meet the acceptance criteria. Problems shall be dealt with immediately until the requirements are met;

2 Constructional quality acceptance of the anti-microvibration engineering shall be in accordance with those specified in Table 8.7.1.

Table 8.7.1 Constructional quality acceptance of the anti microvibration engineering

Items	Content of acceptance	Phase of acceptance
Foundation	Dynamic characteristics and vibration response	Before construction of foundation
		After completion of foundation
Bulk concrete isolation foundation	Dynamic characteristics and vibration response	Before construction of isolation foundation
		After completion of isolation foundation
Building structure for anti-microvibration engineering	Structural dynamic characteristics	After completion of structural facility
	Structural microvibration response	After operation of utility equipment
Anti-microvibration table	Dynamic characteristics of the table	The table is completed, but process equipment have not been installed
	Isolation performance of the table	The table is completed but process equipment have not been installed
		After installation and operation of utility equipment
Air spring isolation	Isolation performance of isolation device	Isolation system is finished, but process equipment have not been installed
		Process equipment have been installed without operation
Active control isolation	Isolation performance of isolation device	Isolation system is finished, but process equipment have not been installed
		After operation of process equipment
Isolation of utility equipment	Transfer rate, resonance performance	After operation of utility equipment
Isolation of pipes	Isolation performance	After operation of utility equipment

8.7.2 If the anti-microvibration engineering is in cleanroom, its acceptance shall meet the requirements specified in the current national standard GB 50591 *Code for Construction and Acceptance of Cleanroom*.

8.7.3 In addition to documents required by relevant codes, the following documents shall be provided in quality acceptance of the anti-microvibration engineering:

1 Detailed drawing for construction, documents of design change and as-built drawing of anti-microvibration engineering;

2 Manufactures' certification and site test reports of major materials, equipment, finished or semi-finished products, and meters;

3 Inspection records of concealed facility of the anti-microvibration engineering;

4 System commissioning records of the anti-microvibration engineering;

5 Performance test reports of the anti-microvibration engineering;

6 Acceptance reports of the anti-microvibration engineering;

7 Operation manuals of the anti-microvibration engineering.

Appendix A Microvibration testing analysis

A.1 General requirements

A.1.1 The following documents shall be prepared for site environment vibration measurement:

1 Allowable value of vibration of precision equipment and instruments;

2 Project geological survey documents of building site;

3 Relevant data of existing buildings nearby, underground pipes, power cables, and etc.;

4 Layout of site and surrounding roads, as well as traffic situation of the roads;

5 Location of vibration source and their operation situation at and near the proposed site;

6 Layout of building structures at the proposed site.

A.1.2 The following documents shall be prepared for microvibration measurement of building:

1 Allowable value of vibration of precision equipment and instruments;

2 The architectural and structural design drawings of buildings;

3 The foundation and cover plates drawings of precision equipment and instruments;

4 Locations and operation situation of vibration sources inside the building;

5 Locations and operation situation of vibration sources outside and near the building.

A.1.3 The following documents shall be prepared for microvibration measurement of anti-microvibration tables:

1 Allowable value of vibration of precision equipment and instruments;

2 Design drawings of anti-microvibration tables;

3 Parameters of isolation device;

4 Data of isolation calculation;

5 Locations of vibration source and operation situation inside the anti-microvibration tables;

6 Locations of surrounding vibration source and operation situation outside and near the anti-microvibration tables.

A.1.4 Before measurement, the site survey shall be conducted and the measurement scheme shall be formulated. The measurement scheme shall include the following contents:

1 Purpose and requirements of measurement;

2 Items and methods of measurement;

3 Layout of measurement points;

4 Measurement instruments;

5 Method for data analysis and processing.

A.1.5 Protective measures to instruments shall be taken during outdoor measurements.

A.1.6 During measurement, measures shall be taken to avoid interference to measurement instruments by strong electromagnetic field and AC power source.

A.2 Measuring equipment and instruments

A.2.1 The measurement system should include vibration sensor, filter, amplifier, signal analyzer and excitation device.

A.2.2 According to the requirements of measurement, integrated high sensitive 3-directional measuring sensor or 3-directional measuring sensor composed of uniaxial sensor shall be selected.

A.2.3 The frequency response range of the sensor shall be selected according to the measurement requirements, which should be 0.5Hz–120Hz for anechoic pool and 0.5Hz–1000Hz for anechoic room.

A.2.4 The amplifier should be a multi-channel amplifier with anti-mixed filtering. At the maximum magnification, the deviation in amplitude consistency of each channel shall be less than 2% and the deviation in phase consistency shall be less than 0.1ms. Amplifiers shall have functions, such as integration and differentiation.

A.2.5 Data acquisition shall adopt a data collection instrument with analog-to-digital conversion. The accuracy of the analog-to-digital converter should be equal to or more than 16 bits and the dynamic range should be equal to or more than 80dB. The amplitude distortion of the data acquisition system shall be less than 1dB.

A.2.6 Data acquisition and analysis software shall have multi-channel display in both time and frequency domains with FFT spectrum analysis.

A.2.7 The excitation device may be either electromagnetic or mechanical. The thrust of electromagnetic exciter should be equal to or more than 2kN, and the operation frequency should be 0.05Hz–1000Hz. The exciting force of mechanical exciter should be equal to or more than 5kN, and the operation frequency should be 3Hz–60Hz.

A.2.8 The vibration measurement system shall be calibrated in the metrological organizations certified by government and shall be used within validity.

A.3 Installation of measuring equipment and instruments

A.3.1 The installation of sensor shall be in accordance with the following requirements:

1 Each measurement point shall be equipped with three uniaxial sensors of the same model or a three-dimensional integrated sensor, and the measuring directions shall be perpendicular to each other to collect the vertical and horizontal vibration data respectively;

2 Three uniaxial piezoelectric acceleration sensors may be fixed at a measuring point by bolts, adhesive or magnetic attraction and on a metal block that is 20 times the mass of the sensor and equal or more than 1kg;

3 A measuring pit at the natural foundation site shall be dug and compacted with soft soil removed. The bottom of the measurement pit shall be poured with a thin layer of concrete;

4 The measuring pit shall be equipped with protective facilities, which must not interfere with normal collection of vibration data.

A.3.2 The installation of electromagnetic exciter shall meet the following requirements:

1 When the electromagnetic exciter is installed vertically, a strong support shall be used, and the vibration exciter shall be suspended from the support with a flexible rubber band. Its inherent frequency shall be one fourth of the lowest measurement frequency;

2 Steel supports shall be used for horizontal exciting, and the vibration exciter shall be horizontally fixed;

3 The exciter shall be connected with the object to be measured by a thrust rod.

A.3.3 The mechanical vibration exciter shall be connected with the object to be measured by bolts.

A.3.4 Grounding measures shall be taken for instrument installation.

A.4 Vibration data acquisition

A.4.1 Before data acquisition, the sensors of the same model shall be sampled and compared.

A.4.2 The sampling frequency shall be more than two times of the cut-off frequency for data analysis, and data number of each sample shall be equal to or more than1024.

A.4.3 The sampling time and times shall be in accordance with the following requirements:

1 For random vibration, it shall be equal to or more than 20min;

2 For steady vibration, it shall be equal to or more than 5min;

3 For mobile vibration sources of same category, it shall be equal to or more than 5 times;

4 For shock vibration of same category, it shall be equal to or more than 5 times.

A.4.4 In each sampling, all the other vibration sources shall stop operation, except for the specified vibration source and combination of vibration sources.

A.4.5 When the exciter is used for excitation, sampling shall starts after the excitation frequency and disturbing force amplitude are stable.

A.5 Site environment vibration measurement

A.5.1 The location of the measuring point for site environment vibration measurement shall be determined according to factors, such as the project scale, the area of the construction site, the location of the building with microvibration requirements, the surrounding roads, and adjacent interference vibration sources. On each site there should be equal to or more than 5 measuring points, and the distance between measuring points should not be more than 40m.

A.5.2 The categorization and combination of environment vibration conditions shall include individual and combined effect of usual environmental micro-vibration as well as fixed and mobile interference vibration sources. The sampling time and times shall comply with A.4.3 of this code.

A.5.3 The influence of personnel walking shall be avoided within 15m around the sensors.

A.5.4 The measurement shall be simultaneous with multiple measuring points. If the number of sensors is insufficient or all measuring points cannot be measured at the same time, it may be measured in batches, while the vibration conditions shall be kept consistent.

A.5.5 When no traffic is available on roads inside and outside the site, vehicles may be used to simulate mobile interference vibration sources. The number of vehicles, load capacity, driving direction and driving speed shall be determined according to the requirements of the measurement.

A.6 Vibration measurement for building

A.6.1 Dynamic characteristic measurement of independent foundation of precision equipment and instruments shall be in accordance with the following requirements:

1 The natural vibration frequency and damping ratio of the foundation may be measured by shock method or resonance method. The sensors shall be set at the centroid projection point on the top surface of the foundation;

2 The dynamic characteristic measurements shall be repeated 3 times at least.

A.6.2 The dynamic characteristic measurement of the building shall be in accordance with the following requirements:

1 The vertical and horizontal dynamic characteristics of building floor shall be measured;

2 Sensors shall be set in the main beam, secondary beam and middle span of slab. For beamless slab structure, sensors shall be set in the middle span of slab.

A.6.3 Environment microvibration measurement shall be in accordance with the following requirements:

1 The category and combination of environment microvibration conditions shall include individual and combined effects of usual environmental micro-vibration and fixed and mobile interference vibration sources inside and outside the building;

2 The setting of sensors shall be in accordance with the following requirements:

1) For the independent foundation of precision equipment or instruments, the sensors shall be set at the center of mass on the top surface of the foundation and at both ends of the long and short sides of the foundation;

2) For floor structures, sensors shall be set at the installation position of precision equipment or instruments, or in the main beam, secondary beam, and middle span of slab.

A.7 Vibration measurement of anti-microvibration tables

A.7.1 The dynamic characteristics measurement shall be in accordance with the following requirements:

1 Before measurement, the isolation system shall be debugged to confirm the normal working state;

2 The dynamic characteristics measurement shall follow provisions of Item 1 of Article A.6.1 of Appendix A in this code;

3 For exceptionally wide or exceptionally long cover plates, structural modes of tables should be measured.

A.7.2 Microvibration measurement shall be in accordance with the following requirements:

1 The category and combination of environment microvibration conditions shall comply with the provisions of Item 1 in Article A.6.3 of Appendix A in this code;

2 Setting of sensors shall be in accordance with the following requirements:

1) The sensors shall be located at the center of mass and both ends of long and short sides of the vibration isolation system on the top surface of the cover plate;

2) The sensors shall be located at the center of mass of the vibration isolation system on the top surface of the cover plate and at the corresponding position of the support structure.

A.8 Vibration data analysis

A.8.1 The pretreatment of vibration data shall be in accordance with the following requirements:

1 Samples collected from microvibration measurement shall be compared with the original measurement records, and valid samples shall be selected for sequencing;

2 Each sample shall be checked and zero point drift and interference shall be removed.

A.8.2 Time domain analysis of vibration data shall be in accordance with the following requirements:

1 For the root mean square values of vibration displacement, velocity and acceleration in time domain, the average method shall be used, and the mean times shall be determined according to the data sampling duration;

2 The peak values of vibration displacement, velocity and acceleration in time domain may be directly determined from the displayed time domain curves.

A.8.3 Frequency domain analysis of vibration data shall be in accordance with the following requirements:

1 Analysis of 1/3 octave spectrum, linear spectrum or power spectrum shall be performed;

2 The Hanning window should be used as the window function;

3 Cut-off analysis for analysis frequency shall be determined as required;

4 The average times of sample signals in frequency domain analysis shall be determined according to the data sampling duration;

5 The linear averaging or peak-keeping averaging shall be used for steady-state or random vibration signals in frequency domain analysis;

6 For mobile vibration source or shock vibration signal, peak-keeping averaging method should be used for frequency domain analysis.

Appendix B Superposition calculation of different and multiple sources vibration

B.1 General requirements

B.1.1 The superposition of vibration responses under multiple vibration sources may be determined by measurement. When measurement is not possible, calculation may be carried out according to Article B.2.1 to B.2.5 of Appendix B.

B.1.2 When the vibration generated by multiple vibration sources transmits and attenuates to the distance r from the vibration sources, the superposition of vibration responses shall be calculated according to the superposition combination of steady vibration, transient vibration, and random vibration sources.

B.2 Calculation of vibration responses superposition under multiple vibration sources

B.2.1 The superposition of vibration responses under multiple different vibration sources may be calculated according to formulas (B.2.2-1) to (B.2.2-4), and the larger value should be used.

B.2.2 The superposition of vibration responses of multiple steady-state vibration sources may be calculated according to formulas (B.2.2-1) to (B.2.2-4):

1 For steady-state vibration sources equal to or less than three:

$$D_r = D_{r_1} + D_{r_2} \tag{B.2.2-1}$$

or

$$D_r = \frac{2}{\sqrt{n}} \sqrt{\sum_{i=1}^{n} D_{r_i}^2} \tag{B.2.2-2}$$

2 For multiple steady state vibration sources:

$$D_r = D_{r_1,\max} + D_{r_2,\max} \tag{B.2.2-3}$$

or

$$D_r = D_{r_1,\max} + \sqrt{\sum_{i=2}^{n} D_{r_i}^2} \tag{B.2.2-4}$$

Where, D_r—superposition of vibration responses of multiple vibration sources at a distance r_i from the specified point;

D_{r_i}—vibration response of each vibration source with a distance from the specified point;

D_{r_1}—vibration response of the first steady-state vibration with a distance from the specified point;

D_{r_2}—vibration response of the second steady-state vibration with a distance from the specified point;

$D_{r_{1,\max}}$—the maximum vibration response among multiple vibration sources with a distance from the specified point;

$D_{r_{2,\max}}$—the second maximum vibration response among multiple vibration sources with a distance from the specified point;

n—number of vibration sources.

B.2.3 The superposition of vibration responses of multiple steady-state and transient vibration sources may be calculated according to the following formulas:

When $D_{w,max} > D_{s,max}$,

$$D_r = D_{w,max} + D_{s,max} \tag{B.2.3-1}$$

When $D_{s,max} > D_{w,max}$,

$$D_r = D_{s,max} + \sqrt{\sum_{i=2}^{n} D_{r_i}^2} \tag{B.2.3-2}$$

Where, $D_{w,max}$—the maximum vibration response among multiple steady-state vibration sources with a distance from the specified point;

$D_{s,max}$—the maximum vibration response among multiple transient vibration sources with a distance from the specified point.

B.2.4 The superposition of vibration responses of random vibration sources, such as trains, cars, and machine tools shall be calculated according to the following formula:

$$D_r = \sqrt{\sum_{i=1}^{n} D_{r_i}^2} \tag{B.2.4}$$

B.2.5 The maximum vibration response value among multiple transient vibration sources shall be used in calculation.

Explanation of wording in this code

1 Words used for different degrees of strictness are explained as follows in order to mark the differences in implementing the requirements of this code.

1)Words denoting a very strict or mandatory requirement:

"Must" is used for affirmation, "must not" for negation.

2)Words denoting a strict requirement under normal conditions:

"Shall" is used for affirmation, "shall not" for negation.

3)Words denoting a permission of a slight choice or an indication of the most suitable choice when conditions permit:

"Should" is used for affirmation, "should not" for negation.

4)"May" is used to express the option available, sometimes with the conditional permit.

2 "Shall comply with..." or "shall meet the requirements of..." is used in this code to indicate that it is necessary to comply with the requirements stipulated in other relative standards and codes.

List of quoted standards

GB 50007 *Code for Design of Building Foundation*

GB 50011 *Code for Seismic Design of Buildings*

GB 50040 *Code for Design of Dynamic Machine Foundation*

GB 50202 *Code for Acceptance of Construction Quality of Building Foundation*

GB 50300 *Unified Standard for Constructional Quality Acceptance of Building Engineering*

GB 50463 *Code for Design of Vibration Isolation*

GB 50591 *Code for Construction and Acceptance of Cleanroom*

JGJ 79 *Technical Code for Ground Treatment of Buildings*