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KOREAN INDUSTRIAL STANDARD

Steel-Laminated Elastomeric Bearings for Bridge

KS F 4420 : 1998

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Steel-laminated elastomeric bearings for bridge

1. Scope

This Korean Industrial Standard specifies the fulfillment conditions such as materials, design, production, quality qualifications and performance test of pot bearings for bridges (hereafter referred to as "pot bearings") used to support their superstructure.

2. Normative reference, symbol and definitions

2.1 Normative reference

The following standards contain provisions, which, through reference in this text, constitute provisions of this standard. The most recent editions of the standards indicated below shall be applied.

KS D 3501 Hot-rolled mild steel plates, sheets and strip.

KS D 3503 Rolled steel for general structure purpose.

KS M 3523 Polytetrafluoroethylene sheets.

KS M 6518 Physical testing methods for vulcanized rubber.

KS M 6783 Tear testing methods for vulcanized rubber.

2.2 Symbol

D : Diameter of round elastomeric bearings.

D : Diameter of round elastomeric bearings with reinforced steel plate.

$F_{z,d}$: Vertical load applied on one elastomeric bearing.

$F_{xy,d}$: The sum of vector quantity of F_x and F_y .

$F_{x,d}$: Horizontal force applied to the X direction.

$F_{y,d}$: Horizontal force applied to the Y direction.

b : Length of elastomeric bearings.

a : Width of elastomeric bearings.

a : Width of reinforced steel plate.

b : Length of elastomeric steel plate.

A_1 : Effective sectional area (effective sectional area, in which horizontal displacement is considered).

A : Sectional area of reinforced steel plate.

$V_{x,d}$: Displacement moved from serviceability limit state (SLS) to X-axis.

$V_{y,d}$: Displacement moved from serviceability limit state (SLS) to Y-axis.

$V_{xy,d}$: Displacement of the sum of vector quantity $V_{x,d}$ and $V_{y,d}$ in serviceability limit state (SLS)

- $\varepsilon_{c,d}$: Compressive strain ratio by vertical load.
- $\varepsilon_{a,d}$: Strain ratio by rotation.
- $\varepsilon_{q,d}$: Shearing strain ratio.
- t_e : Effective thickness of rubber on each layer.
- t_i : Actual thickness (or design thickness) of each layer.
- t_o : Rubber thickness of upper and lower covers enclosing enforced steel plate.
- T_q : Thickness of rubber touched by shearing.
- T_e : Design thickness of rubber.
- n : Number of rubber layers between reinforced steel plates.
- G_k : Characteristic value of modulus of elasticity of shearing.
- G : Modulus of elasticity of shearing.
- S_i : Each shape factor including cover.
- SF : Shape factor.
- α_a : Rotation angle in the width direction of elastomeric bearings (RAD).
- α_b : Rotation angle in the length direction of elastomeric bearings (RAD).
- α_{ab} : Angle of sum of vector quantity of rotation angle in the direction of α_a and α_b (RAD).
- M_e : Test value of restitution moment.
- F : Load required by a lever to rotate up to 0.003RAD.
- L : Length of lever.
- F_k : Yield stress of reinforced steel plate.

2.3 Definitions

a) elastomer

It is a polymeric material returning to its initial size and shape if pressure is removed after it was fairly deformed by a pressure, but it is here one of rubber parts or a chemical compound used to produce rubber parts.

b) elastomeric bearing

A block product reinforced alternately by not less than one steel plate and elastomer.

c) laminated bearing

An elastomeric bearing internally reinforced by combining chemically with rubber when not less than one steel plate is hardened.

d) serviceability limit state (sls)

It is a state on an elastomeric bearing being applied by a load.

e) ultimate limit state (uls)

It is a state on an elastomeric bearing being applied by a greater load than design load.

f) type test

It is a kind of selection test, which shall be repeatedly performed by approved test institution, when a remarkable change has an effect on the conformity with the standard.

g) routine test

It is a kind of control test, which a manufacturer shall conduct regularly.

3. Design specification

3.1 General information

The elastomeric bearing shall satisfy the conditions of 3.2 to 3.3 in both serviceability limit state and ultimate limit state. The elastomeric bearing shall be also free from damages influencing on its functions in the serviceability limit state, and it shall not cost much expenses to maintain and manage it while used. In addition, the strength and stability of a elastomeric bearing in the ultimate limit state shall properly bear the ultimate design load and displacement of a structure.

3.2 Starting design value

The elastomeric bearing is so designed that starting design value S_d shall not exceed the resistance design value R_d/γ_m . In consideration of every primary and secondary sliding effect and the relative replacement specified in general design regulation, the value S_d , which is influenced by supplementary measurement for safety related to the partial safety factor and structure, shall be specified by a engineer in charge of the structure.

The safety factor (γ_m) on elastomeric bearing part takes $\gamma_m = 1.0$ for serviceability limit state under consideration of uncertain factors while manufacturing the elastomeric bearings. If setting error exceeds the limit of the specified permissible error given in 3.4.1, the importance of structure deviation is determined.

3.3 Laminated elastomeric bearing

3.3.1 Type of laminated elastomeric bearing

The elastomeric bearing shall is designed as one of the six types (or the type combined with one of them) indicated in fig. 2.

3.3.2 Shape and dimensions of laminated elastomeric bearing

The shape and dimensions of laminated elastomeric bearing shall be in accordance with fig. 1 and table 1, but other dimensions shall meet the requirement of the design standard of the elastomeric bearing. The shape of the elastomeric shall be square or round, it may be as well shaped in oval or octagon form for a special case.

As for the laminated elastomeric bearings, the loaded area may be reduced without changing the surface dimension, with the hole with the same shaped drilled. As for the standard dimensions of the elastomeric bearings table 1, an elastomeric bearing may be drilled if the total area of holes is not exceeding 5% of the surface of the elastomeric bearing, and if the diameter of every hole is not exceeding 80 mm. In this case, the hole shall be protected from the climate effects.

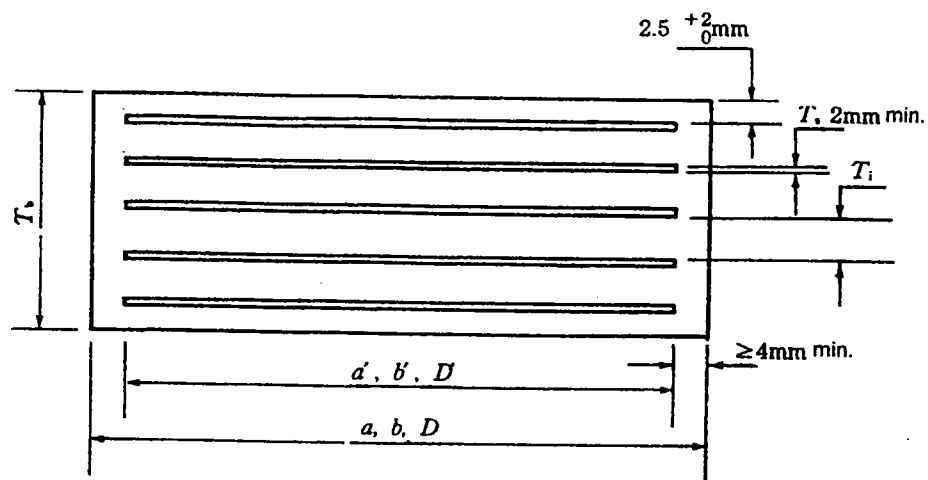


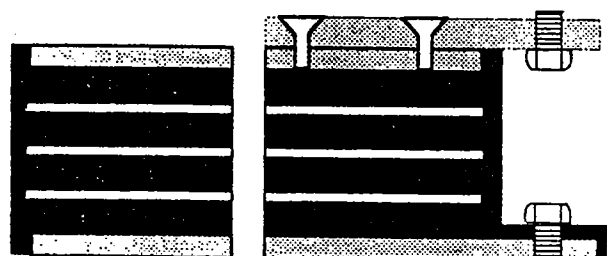
Fig. 1 Typical cross section of an elastomeric bearing



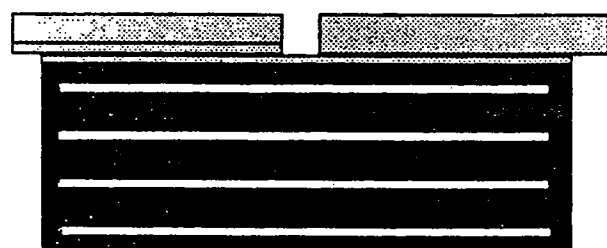
Type A : Laminated elastomeric bearing covering completely only one reinforced steel plate.



Type B : Laminated elastomeric bearing covering completely at least not less than two reinforced steel plates.

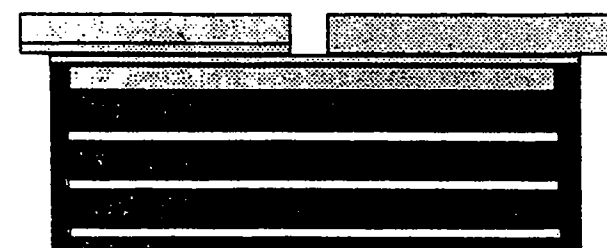


Type C : Elastomeric bearing with reinforced steel plates outside (side view and fixed shape).
(The neighboring figure is an example of the fixing method, and other methods may be applied in accordance with the agreement between the parties concerned).



Type D : Type B + PTFE. It is a type, in which Type B is combined with PTFE elastomer).

* PTFE (Polytetrafluoroethylene)



Type E : It is a type, in which the outside plate is combined PTFE elastomeric bearing whose elastomer and steel plate have hollow spot.



Type F : Elastomeric bearing with flat pad and strip elastomeric bearing.

Fig. 2 Sectional view of elastomeric bearing by type

Remark One of the types above may be combined with another one.

Table 1 Standard dimensions of elastomeric bearings (type B)

Width (a) x length (b) or diameter <i>D</i> (mm)	Thickness (mm)						Number of layers (n)	
	Height (<i>H</i>)		Layer of styrene butadiene rubber		Inside rubber Layer	Reinforced steel plate	Min.	Max.
	Min.	Max.	Min.	Max.				
100 × 150	30	41	16	24	8	3	2	3
100 × 200	30	41	16	24	8	3	2	3
150 × 200	30	52	16	32	8	3	2	4
φ200	30	52	16	32	8	3	2	4
150 × 250	30	52	16	32	8	3	2	4
150 × 300	30	52	16	32	8	3	2	4
φ250	30	52	16	32	8	3	2	4
200 × 250	41	74	24	48	8	3	3	6
200 × 300	41	74	24	48	8	3	3	6
200 × 350	41	74	24	48	8	3	3	6
φ300	41	74	24	48	8	3	3	6
200 × 400	41	74	24	48	8	3	3	6
250 × 300	41	85	24	55	8	3	3	7
φ350	41	85	24	55	8	3	3	7
250 × 400	41	85	24	55	8	3	3	7
300 × 400	57	105	36	72	12	4	3	6
φ400	57	105	36	72	12	4	3	6
300 × 500	57	105	36	72	12	4	3	6
φ450	57	105	36	72	12	4	3	6
300 × 600	57	105	36	72	12	4	3	6
350 × 450	57	121	36	84	12	4	3	7
φ500	57	121	36	84	12	4	3	7
400 × 500	73	137	48	96	12	4	4	8
φ550	73	137	48	96	12	4	4	8
400 × 600	73	137	48	96	12	4	4	8
450 × 600	73	153	48	108	12	4	4	9
φ600	73	153	48	108	12	4	4	9
500 × 600	73	169	48	120	12	4	4	10
φ650	73	169	48	120	12	4	4	10
600 × 600	94	199	64	144	16	5	4	9
φ700	94	199	64	144	16	5	4	9
600 × 700	94	199	64	144	16	5	4	9
φ750	94	199	64	144	16	5	4	9
700 × 700	94	220	64	160	16	5	4	10
φ800	94	220	64	160	16	5	4	10
700 × 800	94	220	64	160	16	5	4	10
φ850	94	220	64	160	16	5	4	10
800 × 800	110	250	80	200	20	5	4	10
φ900	110	250	80	200	20	5	4	10
900 × 900	110	250	80	200	20	5	4	11

Remark Other dimensions except those above may be settled in accordance with the agreement between the parties concerned.

3.3.3 Work tolerance

The tolerance error to the reference value of the product shall be in accordance with table 2.

a) Layer thickness of styrene butadiene rubber

The mean thickness is the arithmetic mean measured from four points on the principal surface of the elastomeric bearing with various shapes.

Rectangle type : Corner.

Round type : Corner of inscribed square.

Oval type : Both edges of long and short axis.

Octagonal type : The middle point of each side of circumscribed rectangle.

Table 2

Unit: mm

Classification		Tolerance
Dimensions of end product	Length	+6 -0
	Width	
	Overall mean thickness (H)	$H \leq 32$: -0, +3 $H > 32$: -0, +6
Thickness of inside rubber layer (t)	All places inside the stay	± 20 of design value. But, it shall be ± 3 mm max.
Parallelism to the opposite side	Upper and lower part	0.005 RAD max.
	Side	0.02 RAD max.
Exposed places of connecting members	Hole, liner or groove	± 3 mm.
Layer of rubber cover	Thickness of upper and lower part	- 0 and +2.0 mm of design value, and smaller value of +20% of nominal thickness of surface layer.
	Thickness of side	- 0 and +2.0 mm of design value.
Size	Hole, liner or groove	+3.0 mm of design value.
Inside reinforced steel plate	Length	+2 -1
	Width	

3.3.4 Design standard

The elastomer is elastic material in design standard, and the bending under compressive load is influenced according to its shape. The reinforced steel plate shall be chemically combined to prevent any relative displacement between steel plate and elastomer.

The elastomeric bearings with standard dimensions indicated in table 1 shall meet the requirements of the specification of 3.3.5, and other elastomeric bearings, which are designed differently, shall satisfy the following specifications:

a) Maximum design strain rate

The sum ($\epsilon_{t,d}$) of nominal strain rate from every places of the elastomeric bearings result from starting design value (S_d) given by the formula below.

$$\epsilon_{t,d} = K_L(\epsilon_{c,d} + \epsilon_{q,d} + \epsilon_{a,d}), \epsilon_{t,d} \leq 5.0$$

Where, $\epsilon_{c,d}$: Nominal strain rate by compressive load specified in 3.3.5 b).

$\epsilon_{q,d}$: Nominal strain rate by moving displacement specified in 3.3.5 c).

$\epsilon_{a,d}$: Nominal strain rate by each rotation specified in 3.3.5 d).

Remark Generally, $K_L = 1.0$, and when the dynamic load is taken into consideration, $K_L = 1.5$.

b) Maximum tensile strength of reinforced steel plate

The maximum tensile strength of reinforced steel plate shall be in accordance with 3.3.5 e).

c) Stability reference

The stability against rotation, the stability against buckling, and the stability against sliding shall be in accordance with 3.3.5 f) respectively.

d) Force applied to structure, moment and strain

Every condition of the following phenomena shall be inspected under design load of the serviceability limit state:

- The pressure on contact surface between elastomeric bearings and structure.
- The force applied to structure by elastomeric bearing resisting moving displacement.
- Restitution moment caused by elastomeric bearing resisting rotative displacement.
- Vertical displacement caused by vertical load.

If the actual breaking strength is too high on the overall elastomeric bearings together with the accommodation of elastomer, it is not necessary to inspect the design load of the ultimate limit state.

- Remarks 1.** The elastomeric bearings shall be so designed that it is working well under the ultimate load of the material, which allows the rubber the fatigue effects. As a result, the elastomeric bearings may take greater momentary load than design value or strain without breaking itself. It is proved that by experiment that the elastomeric bearing is still bearing the load even under large compressive load that may break away a reinforced steel plate. The design value of friction factor under sliding conditions is relatively low to take long-term effects. It will require 2 to 3 times greater force than calculated value at the beginning of the sliding. No more close examination is needed in this state because the elastomeric bearing may resist well against load and strain caused by the ultimate limit state (ULS).
- 2.** The design calculation shall not be applied to outside upper and lower part when the thickness of the top and bottom layer is not more than 2.5mm.
- 3.** The steel part as supporting plate, and PTFE limiting pin shall be in accordance with table 3.

Table 3

Items	Reference values
Tensile strength(kgf/cm ²)	175 min.
Elongation (%)	200 min.
Specific gravity	2.10 to 2.23

- 4.** Nominal shearing coefficient may be increased for dynamic load effects (railway structure, earthquake, etc.) because it depends on exciting frequency and displacement amplitude. This coefficient, which changes from 1.2 to 4 against different compound substances, shall be gained experimentally.

3.3.5 Standard elastomeric bearing

The maximum rotation minimum and maximum pressure applicable to the elastomeric bearing with standard dimensions is indicated in table 4. If the exact value of force, moment, and strain are needed or appointed, they may be gained from the design reference of a) to h).

If they are appointed, the elastomeric bearing shall satisfy the entire or one part of design references given 3.3.4.

Table 4 Permissible pressure and rotation moment of elastomeric bearing

[G coefficient = 9.18 kgf/cm²(0.9 MPa)]

Minimum pressure MPa	σ	Overall dimensions (mm)	Thickness (mm)		Maximum pressure MPa	σ	Rotation angle (rad)		
		Width x length (a) x (b)	Individual rubber layer (t)	Reinforced steel plate (t)			α_a	α_b	α_{ab}
3		100 x 150	8	3	8.0		0.004 0	0.003 0	0.005 0
		100 x 200	8	3	8.0		0.004 0	0.003 0	0.005 0
		150 x 200	8	3	10.0		0.003 0	0.002 5	0.003 9
		150 x 250	8	3	10.0		0.003 0	0.002 5	0.003 9
		200 x 250	8	3	12.5		0.003 0	0.002 5	0.003 9
		200 x 300	8	3	12.5		0.003 0	0.003 0	0.003 6
		200 x 350	8	3	12.5		0.003 0	0.001 5	0.003 4
		200 x 400	8	3	12.5		0.003 0	0.001 2	0.003 2
		250 x 300	8	3	12.5		0.002 5	0.001 5	0.002 9
		250 x 400	8	3	12.5		0.002 5	0.001 0	0.002 7
5		300 x 400	12	4	15.0		0.002 5	0.001 2	0.002 8
		300 x 500	12	4	15.0		0.002 5	0.001 0	0.002 7
		300 x 600	12	4	15.0		0.002 5	0.000 8	0.002 6
		350 x 450	12	4	15.0		0.002 5	0.001 5	0.002 9
		400 x 500	12	4	15.0		0.002 0	0.001 0	0.002 2
		400 x 600	12	4	15.0		0.002 0	0.001 0	0.002 2
		450 x 600	12	4	15.0		0.002 0	0.001 0	0.002 2
		500 x 600	12	4	15.0		0.002 0	0.001 0	0.002 2
		600 x 600	16	5	15.0		0.002 0	0.002 0	0.002 8
		600 x 700	16	5	15.0		0.002 0	0.001 5	0.002 5
		700 x 700	16	5	15.0		0.001 5	0.001 5	0.002 1
		700 x 800	16	5	15.0		0.001 5	0.001 0	0.001 8
		800 x 800	20	5	15.0		0.001 0	0.001 0	0.001 4
		900 x 900	20	5	15.0		0.000 5	0.000 5	0.000 7
Minimum pressure MPa	σ	Diameter(mm)	Thickness (mm)		Maximum pressure MPa	σ	Rotation angle (rad)		
		D	Individual rubber layer (t)	Reinforced steel plate (t)			α_a		
3		200	8	3	10.0		0.004 0		
		250	8	3	12.5		0.003 0		
		300	8	3	12.5		0.002 5		
		350	12	3	12.5		0.002 5		
5		400	12	4	15.0		0.002 0		
		450	12	4	15.0		0.002 0		
		500	12	4	15.0		0.002 0		
		550	12	4	15.0		0.001 5		
		600	16	4	15.0		0.002 0		
		650	16	4	15.0		0.002 0		
		700	16	5	15.0		0.001 5		
		750	16	5	15.0		0.001 5		
		800	16	5	15.0		0.001 0		
		850	16	5	15.0		0.001 0		
		900	20	5	15.0		0.000 5		

Remark Shearing stress may be proved according to the specification of 3.3.5 c), the rotation angle is related to the layer of one elastomer.

a) Shape factor

The shape factor (SF) is the means to explain the rubber shape with for the calculation of strength and strain. It is the rate of effective surface area of free surface area of force and elastic slab including holes. The shape factor SF of each elastomer layer is as follows for the laminated elastomeric bearings.

$$SF = \frac{A'}{l_p \cdot t_e}$$

Where, A' : Effective surface area of elastomeric bearing. It is namely the surface area that the elastomer and steel plate own together except hole area in case that holes will be not filled up later.

l_p : The circumference, with which the force of elastomeric bearing is 0 including the hole circumference in case that holes will be not filled up later.

t_e : Effective thickness of each elastomer layer while pressed. As for the laminated elastomeric bearing, the actual thickness shall be t_i in the inside layer, and it shall be $1.4t_i$ even in the outside layer with not less than 3mm (t_i is the thickness of each elastomer layer).

Remark For the rectangular elastomeric bearing without holes,

$$A' = a' \cdot b', l_p = 2(a' + b')$$

Where, a' : Effective width of elastomeric bearing (namely, the width of reinforced steel plate)

b' : Effective length of elastomeric bearing (namely, the length of reinforced steel plate)

b) Compressive strain ratio by vertical load

The compressive strain ratio ($\epsilon_{c,d}$) caused by vertical load shall comply with the following formula:

$$\epsilon_{c,d} = \frac{1.5 P_{z,d}}{G_d A_1 S'}$$

Where, A_1 : Effective surface area reduced due to load effect.

$$A_1 = A' \left(1 - \frac{V_{x,d}}{a'} - \frac{V_{y,d}}{b'} \right)$$

Where, $V_{x,d}$: Maximum horizontal relative displacement of the elastomeric bearing from direction of dimensions a of elastomeric bearing caused by every design load effect.

$V_{y,d}$: Maximum horizontal relative displacement of the elastomeric bearing from direction of dimensions b of elastomeric bearing caused by every design load effect.

c) Shearing strain ratio

The shearing strain ratio ($\epsilon_{q,d}$) of the elastomer caused by moving displacement shall not exceed 0.7.

$$\epsilon_{q,d} = \frac{V_{xy,d}}{t_q}$$

Where, $V_{xy,d}$: Maximum horizontal relative displacement of the elastomeric bearing gained from the sum of vector quantity.

t_q : Total thickness of the elastomeric bearing from shearing including upper and lower cover.

d) Strain ratio by each rotation

The strain ratio ($\varepsilon_{a,d}$) caused by each rotation shall be as follows:

$$\varepsilon_{a,d} = \frac{(a'^2 \alpha_{a,d} + b'^2 \alpha_{b,d})h}{2\sum(h^2)}$$

Where, $\alpha_{a,d}$: Rotation angle crossing the width a of the elastomeric bearing.

$\alpha_{b,d}$: Rotation angle crossing the length b of the elastomeric bearing.

h : The thickness of each elastomer layer.

e) Thickness of reinforced steel plate

The minimum thickness of reinforced steel plate shall be as follows in the laminated elastomeric bearing that is able to bear tensile stress caused by load.

$$t_s = \frac{1.3 \cdot F_{z,d} \cdot (t_1 + t_2) \cdot \gamma_m}{A_1 \cdot f_k} \text{ and } t_s \geq 2\text{mm}$$

Where, A_1 : Effective estimated area (area of reinforced steel plate) of laminated elastomeric bearing.

$F_{z,d}$: Vertical design load.

F_z : Normal force

t_1, t_2 : The thickness of each elastomer layer on each surface of the plate.

f_k : Yield stress of steel.

γ_m : As partial safety factor, $\gamma_m = 1$ with holes.

$\gamma_m = 2$ without holes.

f) Stability standard**1) Rotation stability**

The ultimate rotation on the laminated elastomeric bearing is satisfied when total vertical strain is greater than the specified value below.

$$\text{Square elastomeric bearing } \Sigma V_{z,d} \geq \frac{(a' \cdot \alpha_a + b' \cdot \alpha_b)}{Kr}$$

$$\text{Round elastomeric bearing } \Sigma V_{z,d} \geq \frac{D \cdot \alpha}{Kr}$$

Where, D : Diameter

2) Buckling stability

The pressure on the laminated elastomeric bearing shall satisfy the following conditions:

$$\text{Square elastomeric bearing } \frac{F_{z,d}}{A_1} \leq \frac{2 \cdot a \cdot G - S'}{3 \cdot T_e}$$

a' shall be considered as diameter on the elastomeric bearing.

3) Sliding stability

The sliding stability shall be properly considered under the conditions of every load.

$$F_{xy,d} \leq \mu_e \cdot F_{d,min} \text{ and } \sigma_m \geq 3\text{N/m}^2$$

Where, $F_{xy,d}$: Sum of every horizontal force.