The maximum transverse inclination of the rail at the spots at which the car is likely to come to a full stop for operational reasons (e.g. at safety brakes) shall be limited to a maximum value of 25°. The path of the rail track shall be selected in such a way that the changes in acceleration do not exceed 2 g.

The car velocity can be determined for the mass point in accordance with formula (80).

Key to symbols used in formulae 70 to 80:

- a wheel gauge;
- e distance of centre of gravity;
- α theoretical transverse inclination of rail;
- β actual transverse inclination of rail;
- γ longitudinal gradient of rail;
- δ setting angle of guide rollers;
- $\bar{R}_v$ vertical radius of rail axis;
- $\bar{R}_h$ horizontal radius of rail axis;
- $\pm R_v$ vertical radius of the mass centre of gravity (+ ≙ trough; − ≙ hump);
- R_h horizontal radius of the mass centre of gravity;
- C_v vertical centrifugal force;
- C_h horizontal centrifugal force;
- F_{res} resultant load;
- V load from R vertical to the rail;
- H load from R horizontal to the rail;
- μ_1 coefficient of friction between wheels and rail;
- $\bar{\mu}$ coefficient of friction between guide wheels and rail;
- f lever arm of friction;
- μ_2 coefficient of friction of the antifriction bearings;
- A application surface which the car presents to the wind;

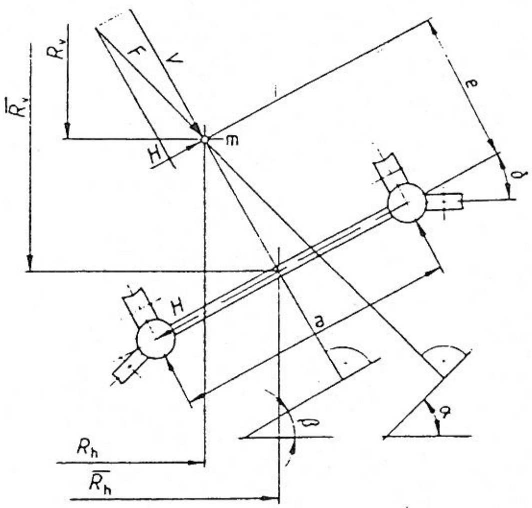

Figure 12. Rail cross section with support and guide rollers

- c_f shape coefficient;
- h (= $h_1 - h_2$) differential height;
- Q car load and imposed load;
- m mass
- D_1 diameter of running wheel;
- D_2 diameter of guide wheel;
- d_1 diameter of running wheel axle;
- d_2 diameter of guide wheel axle;
- v_1 velocity at point 1;
- v_2 velocity at point 2;
- l actual rail length from point 1 to point 2;
- h_1 elevation at point 1;
- h_2 elevation at point 2;
- ϱ density of the air;

Formulae

$$R_h = \bar{R}_h - e \cdot \sin\beta \quad (70)$$

$$R_v = \bar{R}_v - e \cdot \cos\beta \quad (71)$$

$$m = \frac{Q}{g} \quad (72)$$

$$C_v = m \cdot \frac{v_m^2}{R_v} \quad (73)$$

$$C_h = m \cdot \frac{v_m^2 \cos^2\gamma}{R_h} \quad (74)$$

$$v_m = \frac{v_1 + v_2}{2} \quad (75)$$

$$F = \sqrt{(Q \cdot \cos\gamma + C_v)^2 + C_h^2} \quad (76)$$

$$V = F \cdot \cos(\alpha - \beta) \quad (77)$$

$$H = F \cdot \sin(\alpha - \beta) \quad (78)$$

$$\tan\alpha = \frac{v_m^2 \cos^2\gamma}{R_h\left(g \cdot \cos\gamma + \frac{v_m^2}{R_v}\right)} \quad (69a)$$

Friction coefficients

$$\mu_1 = \frac{2f}{D_1} \quad (79)$$

$$\bar{\mu}_1 = \frac{2f}{D_2} \quad (79a)$$

All forces are related to interval centre, and the interval length to be selected shall be the spacing between adjoining support columns, however not exceeding 5 m.

$$\boxed{v_2^2 = v_1^2 + 2g \cdot h - c_f \cdot A \cdot \varrho \cdot v_m^2 \cdot \frac{l}{m} - \left(\mu_1 + \mu_2 \frac{d_1}{D_1}\right) \frac{2 \cdot l}{m} \left(V + |H| \cdot \tan\delta\right) - \frac{|H|}{\cos\delta} \left(\bar{\mu}_1 + \mu_2 \frac{d_2}{D_2}\right) \frac{2 \cdot l}{m}} \qquad (80)$$

If we insert all the values:

$$v_2^2 = v_1^2 + 2g \cdot h - c_f \cdot A \cdot \varrho \cdot v_m^2 \cdot \frac{l}{m} - \Bigg] \sqrt{\left(Q \cdot \cos\gamma + m \frac{v_m^2}{R_v}\right)^2 + \left(m \frac{v_m^2 \cdot \cos^2\gamma}{R_h}\right)^2}$$

$$\cdot \cos\left[\arc\tan \frac{v_m^2 \cdot \cos^2\gamma}{R_h\left(g \cdot \cos\gamma + \frac{v_m^2}{R_v}\right)} - \beta\right] \cdot \left(\mu_1 + \mu_2 \frac{d_1}{D_1}\right) \frac{2 \cdot l}{m}$$

$$- \frac{1}{\cos\delta} \Bigg] \sqrt{\left(Q \cdot \cos\gamma + m \frac{v_m^2}{R_v}\right)^2 + \left(m \frac{v_m^2 \cdot \cos^2\gamma}{R_h}\right)^2} \cdot \sin\left|\left[\arc\tan \frac{v_m^2 \cdot \cos^2\gamma}{R_h\left(g \cdot \cos\gamma + \frac{v_m^2}{R_v}\right)} - \beta\right]\right|$$

$$\cdot \left(\bar{\mu}_1 + \mu_2 \frac{d_2}{D_2}\right) \frac{2 \cdot l}{m} - \tan\delta \Bigg] \sqrt{\left(Q \cdot \cos\gamma + m \frac{v_m^2}{R_v}\right)^2 + \left(m \cdot \frac{v_m^2 \cos^2\gamma}{R_h}\right)^2}$$

$$\cdot \sin\left|\left[\arc\tan \frac{v_m^2 \cdot \cos^2\gamma}{R_h\left(g \cdot \cos\gamma + \frac{v_m^2}{R_v}\right)} - \beta\right]\right| \cdot \left(\mu_1 + \mu_2 \frac{d_1}{D_1}\right) \frac{2 \cdot l}{m}$$

The formula shall be evaluated by iteration with $v_m = \frac{v_1 + v_2}{2}$.

Because the friction coefficients are liable to considerable variations in magnitude as a result of the running-in time, the design, the surface finish of the rail and the weather, it will be necessary to carry out a measurement of the actual velocity. There shall be an adequate degree of consistency with the calculated values.

5.5.2 Supporting framework

If one reckons with continuous effect for the running rail above the support columns, one shall take into consideration a column settlement by virtue of the reduction by 50% of the moment at support, and a column heightening by virtue of the increase by 25% of the moment at support. The increase or reduction of these moments need not be taken into consideration for the verification of the operating strength in view of the low numbers of cycles anticipated. The conductance of all the forces shall be verified as nearly as possible to the actual conditions, taking the rigidity conditions into consideration.

For exposed support trestles anchored above the rails in the overall structure, the assessment of the wind load may be ignored for the verification of the stability and of the safety against sliding. The safety of the installation against overturning, when it is subjected to wind load, need not be verified as a general rule, unless exceptionally large horizontal forces are likely to arise as a result of a particularly unfavourable shape or of exceptionally large wind load areas of the framework components (decorations, lighting strips), or as a result of partial or total cladding of the framework or track.

5.5.3 Vehicles

The cars shall be designed in such a way, in respect of passenger accommodation, that every passenger is safely accommodated. The passenger shall have a sufficient hold on the seat, on the back and arm rests to counteract the contact pressure forces which arise during the ride as a matter of course.

The cars shall be designed in such a way that the passengers inside and outside are not liable to come in contact with moving parts, and also in such a way that passengers' hands or arms are not liable to be crushed or bruised by contact with the cars in front or behind the one they are travelling in. The chassis and superstructures of the cars shall be designed in such a way that they do not sustain any uncontrollable constraint forces arising from changes in transverse inclination, curves, humps and troughs, also allowing for permissible wear. All the forces which arise shall be followed in the calculation from their point of origin right down to the supports. Thus for example, in the case of cars with one oscillating and one rigid axle, the moments from forces transverse to the car above the oscillating axle can only be absorbed by the rigid axle. Forces transverse to the car can for example only be led away via wheels which run up against the rail.

The travelling gear shall be equipped with devices for the prevention of derailment and lift-off. If the travelling rollers are not designed in such a way that they are also capable of absorbing sideway forces, then special guide rollers shall be provided for this purpose.

Safety devices against lift-off (rollers or claws) shall be sized for 50 % of the pro-rata fully occupied vehicle weight, unless calculations indicate that greater forces are involved.

5.5.4 Brakes

5.5.4.1 The cars are braked at the end of the descent by stopping brakes after each journey.

In the event of delays during change of passengers, any risk of collision by following cars shall be prevented with absolute certainty by appropriate means. Each stopping brake shall be designed in such a way that the braking deceleration does not exceed a maximum value of 4,0 m/s^2, as a general rule 2).

5.5.4.2 Safety brakes in the downhill stretch shall be arranged for the planned minimum distance between successive cars in such a way that there will always be one brake between any two cars.

Each safety brake shall be designed in such a way that the braking retardation does not exceed a maximum value of 7,0 m/s^2.2) .75 g (lower than Spec mtn)

The operating strength need not be verified in respect of safety brakes.

As regards the design in respect of retardation, the assessment shall be made on the basis of the highest attainable friction coefficient for the selected brake surface materials.

With regard to the sizing of the effective slowing down length, one shall proceed from the assumption that the car is still able to come to a full stop with a safety factor of 1,2 (related to the friction coefficient), even when the minimum friction coefficient due to weather influences and wear is adopted. If the actuating force has to be increased in order to compensate for varying friction coefficients (ignoring small changes as a result of wear), this shall be taken into consideration. The limiting values shall be checked on the finished installation, and in this connection the minimum friction shall as far as possible be produced for the rail as well, but in any event at least for the brake surfaces, for example by lubrication with water.

5.5.4.3 Reducing brakes shall be sized in respect of operating strength (see subclause 5.5.4.1 re. retardation).

2) Greater retardations are permitted on condition that special devices for the protection of the passenger are provided.

5.5.5 Safety devices to prevent running back

Installations on which the cars or trains are conveyed on the ascent ramp by means of chains, ropes, friction wheels or by self-propulsion, shall be provided on the ascent ramp with safety devices to prevent running back, or with automatically acting brakes or ratchets to prevent running back.

If it is planned that several cars or trains are to be present at the same time on the stretch of track situated between the end of the lift or ascent ramp and the station, or the brake situated before the station, then safety devices to prevent running back shall also be fitted in the uphill stretches of the track after the valleys.

The climb elevation h up to the beginning of the safety device against running back, or the maximum speed which can arise during running back shall not exceed the following limiting values. At least one of the following two limiting values each shall be complied with:

h = 7 m, v = 42 km/h for a straight line backward run without transverse rail inclination, when viewed from above;

h = 5 m, v = 35 km/h for a backward run on a wide sweep curve, with a transverse rail inclination up to 20°;

h = 3,5 m, v = 30 km/h for a backward run on a sharper bend, with a transverse rail inclination exceeding 20°.

Two values shall be specified, because h is a function of the elevation of the centre of gravity of the train, in the case of trains, and this elevation need not necessarily be the same as the climb elevation. Furthermore, the location on the train of the safety device against backward running is of importance for the above-mentioned limiting values.

If, according to plan, it is intended that there is to be only a single car or a single train on the track at any one time, safety devices against running back can be omitted from the uphill stretches after the valleys. In addition, if the car or train is able to travel backwards at full speed through the station platforms without any danger to the passengers sitting in the car or train, and if the station platforms are kept free of visitors during the journey of the car or train, then safety devices against running back can also be omitted from the ascent ramps. As a general rule, this is possible in the case of installations on which the total stretch of track is traversed several times in succession by the occupied cars during one tour. If there are several cars or trains on the track, one can dispense with safety devices against running back on the uphill stretches, on condition that the individual track sections are safeguarded by a fool-proof block system with automatically controlled brakes.

The operating strength need not be verified for safety devices against running back. If the car is stopped in the safety device against running back with a sudden jerk, then an impact factor shall be assumed for dimensioning purposes, which is to be entered at a value of at least one half of the maximum running back elevation, in cm, if no exact verification is carried out, and which is not to be less than 2,0. A load of $\varphi \cdot Q$ shall be assumed for dimensioning purposes.

5.6 Other railways with rail track bound vehicles

(Childrens' railways, childrens' traffic gardens, ghost railways and similar installations, with both conventional and suspended vehicles).

The requirements outlined in subclause 5.5 shall apply for dimensioning and for the operating safety, as far as applicable.

The cars shall be fitted with fenders at the front and rear, which are to be mounted at the same height. If there is an offset during contact, e.g. as a result of longitudinal or transverse swinging, then the fenders shall have a sufficient height to provide overlap. At least one fender per car shall be spring-mounted for shock absorbing purposes, the damping being designed in function of the nominal speed. Damping may be dispensed with if the cars are safeguarded against collision by a block system (section safety system).

If track girders and supports form an integral part of the roofing structure, they shall be dimensioned for the oscillating load in respect of operating strength.

For suspension railways, free spaces of an order of magnitude of the calculated swinging motion, with an added safety margin, shall be provided both to the excursion side and to the opposite side, in addition to the clearance in accordance with subclause 5.5.1. The added safety margin shall be not less than 10 % of the calculated excursion angle, with a minimum value of 5°. The oscillation behaviour shall be borne in mind when calculating the excursion angle.

The accelerations arising from the oscillating motions of the gondola shall be taken into account in the calculations for the vehicle, the rail and the supports.

If dampers are provided for the lateral oscillations of pendulum gondolas, and if the clearance is inadequate for an undamped oscillation, pendulum movement limitations shall be provided.

At the beginning of route sections in which pendulum gondolas are guided (e.g. in the region of passenger transfers), suitable guides shall be provided, which are capable of grasping the gondolas up to twice the value at least of the existing calculated excursion angle, and of guiding them in as smoothly as possible in harmony with the travelling speed.

The locking of pendulum gondolas for the purpose of passenger transfers can only be dispensed with on condition that no danger or inconvenience to the passengers is caused by the adoption of other means (e.g. very powerful dampers).

5.7 Motorcar driving installations

5.7.1 Motorcar driving installations with carriageways for one direction of driving only (e.g. car racing tracks, multi-storey car tracks, go-cart tracks, motor scooter tracks)

5.7.1.1 Carriageways

The carriageway slopes shall be designed in accordance with the radii of the bends and the maximum vehicle speed. Longitudinal and transverse gradients shall not exceed values which would cause braked vehicles to skid or slide on a wet carriageway. The carriageway shall not exhibit any humps likely to cause the wheels to lift off. In the region of the station, the carriageway shall not exhibit any slopes.

The carriageway surfacing shall be manufactured in such a way, and the carriageway itself shall be dimensioned in such a way that no vibrations and only mild shocks can occur.

The sag of the carriageway shall not exceed $l/500$ of the span.

5.7.1.2 Carriageway crash barriers

The carriageways shall be provided with carriageway crash barriers on the sides.

The collision load shall be determined in accordance with subclause 4.4.3 for α not less than 30°.

5.7.1.3 Carriageway supporting frameworks

When sizing the carriageway supporting frameworks, the starting, braking and centrifugal forces shall be taken into consideration as horizontal forces by the provision of appropriate bracings or frame structures.

Unless a more accurate assessment is carried out, 30 km/h shall be used as maximum speed of the vehicles in the calculation of the action of the force.

The carriageway supporting frameworks are structures subjected to vibratory stresses, in respect of which the operating strength is to be verified.

5.7.1.4 Vehicles

The vehicles shall be designed and constructed in such a way that the forces arising during operation (e.g. the braking forces), also the forces resulting from ramming or collisions, and the contact pressure exerted by the passengers on the vehicle (seat, arm rests, back rest, front panel, steering wheel) can all be absorbed.

The fenders equipped with springs and damping devices, which are provided for the alleviation of the collision, shall be designed and sized in such a way that the maximum forces acting on the passengers remain bearable.

The fenders on all the vehicles used on a carriageway shall exhibit the same height and shall be matched to the height of the carriageway crash barriers.

5.7.1.5 Imposed loads

The imposed load on the carriageway shall consist of the fully-loaded vehicles arranged next to one another and behind one another in the most unfavourable position. In this context, any wheel loads which might exert a load-relieving effect shall be ignored.

All structural components shall also be calculated for an additional loading case, viz. for a uniformly distributed imposed load p = 2 kN/m^2, and 3,5 kN/m^2 in the station zone. The more unfavourable of these two values shall be used for dimensioning purposes.

5.7.2 Driving installations with arbitrary directions of driving (autoscooters)

5.7.2.1 Roofing-over structure

Apart from the dead loads and wind loads, the roof structure of the autoscooters shall absorb the forces due to the prestressing of the electric network. If a more precise assessment is not made, a force of 0,3 kN/ shall be assumed for this purpose.

The supports of the roofing-over structure may be attached to the carriageway structure and the latter may be partially called upon to absorb lifting-off forces from the supports. They shall be effectively protected against collisions from the vehicles by structural measures.

5.7.2.2 Surface of carriageway

The surface of the carriageway of autoscooters shall be laid without gaps between joints. The slabs shall be sized for a uniformly distributed loading of 3,5 kN/m^2, and, in a second calculation procedure, for the most unfavourable wheel loads on a fully occupied carriageway surface.

The slabs shall rest at the edges on the longitudinal and/or transverse girders in an immovable manner.

The sag of the slabs shall not exceed $l/500$ of the span.

5.7.2.3 Carriageway crash barriers

The collision load shall be determined in accordance with subclause 4.4.3 for $\alpha = 90°$.

5.7.2.4 Supporting structure

The timber packings of the longitudinal and transverse girders shall be marked on the drawings. Their spacing shall be determined in such a way that the calculated sag of the girders does not exceed $l/500$.

The stairs and platforms of autoscooter installations shall be calculated for a uniformly distributed loading of 5 kN/m^2.

5.7.2.5 Vehicles

Subclause 5.7.1.4 shall apply as appropriate.

5.8 Steep wall tracks

5.8.1 Steep wall tracks shall be calculated for the operational loading, apart form the loads specified in clause 4.

As far as the operational loading is concerned, the nature of the displays, the number of vehicles operating at the same time, and their most unfavourable position in relation to each other shall be taken into account. If no special measurement values are available, the centrifugal force can be entered as follows in the calculation:

not less than four times the mass of the vehicle (including driver), for two-wheeled vehicles;

not less than three times the mass of the vehicle (including driver), for four-wheeled vehicles.

5.8.2 Steep wall tracks shall be roofed over at least to an extent which affords total protection against the weather to the track itself.

The top rim of the track shall be provided with a boundary designed to prevent the vehicles from travelling over the edge of the track and crashing into the spectators' enclosure (e.g. by means of a steel wire rope of not less than 13 mm diameter running right around the periphery).

The distance from the surface of the track to this boundary wire rope shall be not less than 60 cm radially inwards.

5.9 Globes

Globes shall be erected inside or under the roofing-over structure in such a way that their tracks are completely sheltered from the weather.

Globes shall be calculated for the operational loading, in addition to the calculation for the loads specified in clause 4, and for this purpose, the most unfavourable combination arising from the type, number and position of the vehicles used shall be adopted.

The fencing off of the spectators' enclosure shall exhibit a diameter not less than 2 m greater than the diameter of the globe.

5.10 Installations for artistic aerial displays

A verification in accordance with subclause 2.4 shall be carried out in respect of the frames, supports, wire ropes and anchorages of high wire installations, and also in respect of the supporting masts of swing mast installations.

Because the carrying wire rope (travel rope or walking rope) of high wire installations is frequently attached to existing structures at one end, and sometimes at both ends, it is necessary for the various possible types of construction of the attachments to be illustrated and verified by calculation in the technical documents, apart from a specification of the attachment force. All the display acts shall be described in the technical documents, and the most unfavourable loadings shall be deduced therefrom, on the basis of which strength and stability are to be verified.

So-called swing masts mounted on supporting masts regularly exceed the permissible slenderness ratio and cannot therefore be calculated in respect of safety against buckling.

In order to secure the swing mast against crashing down, a steel wire rope of 6 mm diameter at least shall be threaded through the hollow interior of the swing mast, and tied to the upper ends of the swing mast and of the supporting mast.

5.11 Rotors

Uniformly distributed loads and partial loadings shall be taken into account for rotors.

The cylinder of the rotor shall be calculated for a one-sided imposed load on one quarter or three quarters of the periphery, in addition to the self weight and uniformly distributed imposed load calculation; in this connection, a knife-edge load of p_v = 1,2 kN/m, distributed on the periphery, shall be assumed. In addition, the loading case which involves two loaded quadrants situated opposite one another and the remaining two quadrants unloaded, shall also be calculated. The centrifugal force generated by the passengers may be assumed to act at a height of 1,2 m above the highest position of the bottom of the cylinder, and it shall be entered in the calculation at the value resulting from the rotational speed concerned.

If the symmetry of the supporting wall is interrupted for example by door openings, the influence of these shall be verified. Similarly, the influence of supporting wheels or guide wheels shall be verified if necessary.

The floor shall also be calculated for a loading case in which the total number of passengers admitted all crowded together on a floor sector with a central angle $\alpha = 120°$.

The locking devices and fastenings of the cylinder doors shall also be checked by calculation.

5.12 Toboggans

Apart from dead load and wind load, toboggans shall be calculated for the following imposed loads:

area of inclined elevator conveyor belt:	2,0 kN/m^2;
upward slopes, steps, platforms:	5,0 kN/m^2;
sliding tub per chute:	1,5 kN/m;
simultaneous horizontal loading on the upper edge of the tub (outer side of curve):	0,25 kN/m.

5.13 Rolling barrels

Rolling barrels shall only be calculated for an imposed load of 2,5 kN/m, this corresponds to a load per unit area of 2,5 kN/m², if one assumes a walked-over width of 1 m. The stability of the rolling barrel shall be verified for the case in which this loading is situated on the side wall at midpoint height. If the support rollers are more than $l/5$ distant from the end of the barrel, the stability shall also be verified in relation to a transverse axis.

5.14 Travelling platforms

Travelling platforms shall be calculated for an imposed load of 3,5 kN/m². In addition to full load, they shall be verified in respect of the most unfavourable part loading; in particular, the portions which project beyond their supports shall be assumed to be loaded; the stability of these shall also be verified.

Balustrades and railings of travelling platforms shall be calculated for a horizontal lateral force of 1,5 kN/m at spar height.

5.15 Turntables (devil's wheels and the like)

Turntables shall be verified, apart from the dead load, for an imposed load of 3,5 kN/m² in the stationary state, and for an imposed load of 2,0 kN/m² in operation at maximum rotational speed.

These loads shall also be assumed to act unsymmetrically on a floor sector with a central angle of 90°.

The fixed floors contiguous to the turntables shall be calculated for an imposed load of 5 kN/m².

The catcher cushions for the people sliding off the turntable shall be calculated for a horizontal concentrated load of 2,5 kN at the most unfavourable spot, or for a uniformly distributed horizontal loading of 2 kN/m.

5.16 Grandstands

Apart from the usual stability verification in accordance with subclause 2.4, special attention shall be paid to the verification of safety against overturning, if the grandstands are roofed over, or if numerous flags or banners are attached to the grandstands.

The floor slabs of grandstands shall be firmly attached to the supporting structure, to prevent them from sliding.

5.17 Roofing-over structures (e.g. enclosed or open hangars, tents or marquees, membrane structures)

5.17.1 General

a) Structures with a primary load bearing structure (e.g. roof truss hangars) and with elements which seal the structure off from the outside (e.g. cotton or synthetic fabric tissues, solid sheeting etc.);

b) structures with mechanically tautened primary loadbearing membranes (e.g. membrane structures, sails etc.).

We are dealing here with roofing-over structures of arbitrary shape, using flexible membrane materials (e.g. coated synthetic fibre tissues) subjected to tensile stress as the loadbearing structural component.

Because a failure of the loadbearing membrane material dealt with in item b) could lead to a complete collapse of the entire structure, special requirements shall be met by the membrane material and by the overall loadbearing structure (see subclause 5.17.4).

5.17.2 Materials for elements which seal the structure off from the outside

Cotton tissues.

Synthetic fabric tissues.

Solid covering and sheeting such as sectional steel sheets, wood, asbestos cement or plastic panels and multicomponent elements.

For structures in accordance with subclause 5.17.1 b), the suitability of the material and of the jointing and fastening techniques shall be demonstrated e.g. by virtue of a general building inspectorate approval.

5.17.3 Structures with primary loadbearing structure (e.g. roof truss hangars)

5.17.3.1 Restraint

Where frame legs are driven into the ground, an end restraint in the foundation soil not exceeding 80 % may be reckoned on. An analysis of the reaction in the foundation soil is required, and in this context a ground bearing pressure of 0,15 MN/m² shall not be exceeded.

5.17.3.2 Ground surcharges and anchorages for protection against wind suction loads (see also subclause 6.2)

In the case of hangars, show booths and the like, mountings for the absorption of forces may be included in the calculation, on condition that they will be activated without any doubt, and that they will be mounted in the same fashion at every installation.

5.17.3.3 Wind bracings

The forces acting on the gables shall be capable of being absorbed by the bracings to be arranged in the roof and wall plane. It is also permitted to arrange two bracings immediately behind one another in each case, each designed to absorb one half of the load acting on the gable wall. The intermediate bracings shall in each case be sized for not less than half the wind load acting on the gable wall. No more than six panels free of bracings at the very most may be situated between the bracings. If no wind forces from the gable walls act on the roof and wall plane, bracings designed for not less than half the wind load which would act on the gable wall shall nevertheless be provided in this case also.

If angled chords are incorporated in the wind bracing, the deflection forces which arise shall be taken into account (e.g. at the ridge of gabled roofs). If necessary, the forces for the stabilization of the roof trusses shall also be taken into account in the sizing of the bracings.

5.17.3.4 Membrane forces due to wind

Wind acting on the flexible elements which seal the structure off from the outside generates one-sided traction forces particularly in the end spans. These forces shall be estimated. Their absorption by all the edge girders (ridge purlins, eaves purlins, roof truss girders and corner posts) shall be checked. This proportion of the force may be reduced to 60 % for the conductance of the forces which arise when the gable walls are subjected to an oncoming flow via the wind bracings (overall system).

The increased edge suction loads can be ignored for flexible wall and roof surfaces. As regards rigid roof coverings, the fastening means shall be sized in accordance with DIN 1055 Part 4 in respect of the increased edge suction loads.

The displacements of the corner points of the frame trusses in the horizontal direction shall not exceed $(l + h)/125$, where l is the distance of the base points of the truss and h is the eaves height. For multi-nave hangars the values applying to the largest hangar shall be adopted.

5.17.4 Structures with mechanically tensioned primary loadbearing membranes (e.g. membrane tents, sails etc.)

5.17.4.1 General

Accurate verification in respect of membranes which are curved without exception in opposite directions for stability reasons can only be carried out in accordance with higher order theory. As a general rule, this procedure is too complicated and expensive, and consequently it can be dispensed with if the verification is carried out in respect of the non-deformed system, and if part systems are set in equilibrium individually in each case. This may result in incompatibilities in the deformed system, but these can be ignored, because verification in accordance with first order theory is generally on the safe side.

As regards the individual verification of the membrane structure, the stress shall always be investigated in the direction of the main loadbearing axis and also at right angles to this axis. This can however be dispensed with if the ratio of the two curvatures in relation to one another is less than 1/3, and the membrane can then be assumed as being uniaxially loadbearing.

5.17.4.2 Prestressing

The structure shall be mechanically prestressed in order to stabilize the membrane structure against the external loads which arise, and also in order to prevent any whip, flutter or breakdown. This prestressing shall be applied at the edges of the structure. Empirical values for it are given below:

F_V = 0,50 kN/m for small structures	$A <$ 400 m^2 and $h <$ 8 m;
F_V = 0,80 kN/m for	$A \geq$ 400 m^2 and $h <$ 8 m;
F_V = 1,0 kN/m for	$A <$ 1000 m^2 and $h \geq$ 8 m;
F_V = 1,5 kN/m for all other structures.	

This permanent working load of the membrane at the edge of the structure shall not exceed 3 % of the short duration tearing load (the permanent working load is the permanently present prestressing). A superposition of the prestressing loading case onto other loading cases shall only be carried out if the stress is increased thereby.

5.17.4.3 Wind on the membrane loadbearing structure

An accurate determination of the wind load distribution can be dispensed with if the procedure in accordance with subclause 5.17.4.1 and subclause 5.17.4.2 is followed, and if the shape coefficients are lumped together in accordance with the graphic representation below:

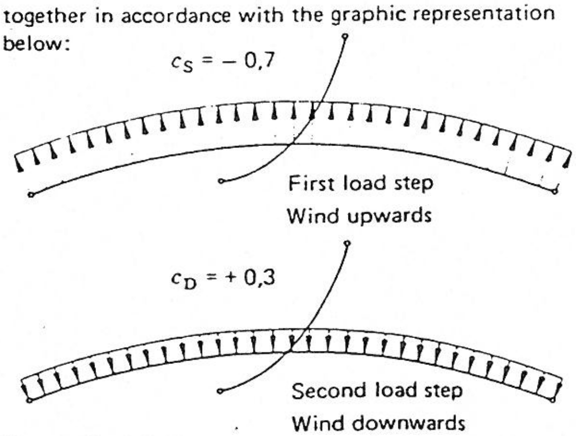

Figure 13. Wind coefficients

The total area and the partial area also shall be loaded taking these values into consideration.

If more favourable values are entered in the calculation, they shall be substantiated by wind tunnel tests.

5.17.4.4 Design and construction details

The pattern of the course shall be laid in accordance with the main stress.

If rope, belt or membrane reinforcements are fitted, care shall be taken to ensure that no weakening of the material cross section occurs at these places (e.g. due to an accumulation of stitches, clips, eyelets etc.), which would nullify the effect of the reinforcement.

5.17.4.5 Safety margins, safeguards

Because membrane loadbearing structures are subject in part to considerable deformations under load, care shall be taken to ensure that no objects which might hinder the deformation are present along the roof membrane.

The following safety margins shall be observed.

For membranes:

$a \geq \frac{r}{20} \geq 0{,}50$ m, where r is the smaller main radius of curvature in the relevant zone of the membrane.

For ropes:

$a \geq \frac{l}{20} \geq 0{,}50$ m on all sides from the middle of the rope; a may be moved linearly to zero in the direction of true fixed points.

l is the distance of the fixed rope suspension.

In so far as rigid loadbearing components (e.g. masts, supports etc.) are restrained solely by the membrane, the overturning of such components in the event of a one-sided removal of the membrane shall be prevented by additional measures, and the necessary degrees of freedom of movement in the operating condition shall remain intact.

5.17.4.6 Check measurements, post-tensioning

In order to have the possibility of checking the maximum stresses which arise on the structure (e.g. in guy ropes, bracings, supports, masts etc.) measuring markings shall be incorporated, so that the necessary calculated degree of prestressing can be verified by suitable checks. Design measures which enable a post-tensioning of the structure to be effected shall be incorporated (e.g. turnbuckles, support extensions etc.), for the purpose of compensating the creep of the membrane loadbearing structure (e.g. the creep of the membrane material, of the stitching, of the fastenings, of the ropes etc.).

6 Overturning, sliding and lifting

6.1 Safety against overturning, sliding and lifting

Safety against overturning, sliding and lifting of structures and structural components shall be verified unless it is self-evident without any doubt. Imposed loads which act favourably, and dead loads of structural components and accessories which are not present (in situ) at all times shall not be included in the verification of safety against overturning, sliding and lifting.

Contrary to the assumptions made for the general stress analysis, those portions of the structure which exert a favourable effect shall only be entered in the calculation of safety against overturning, sliding and lifting at a mass which can be guaranteed to exist in all circumstances; for example, wood shall always be entered in the fully dried-out state.

If an adequate degree of safety cannot be achieved by virtue of the dead load of a structure alone, then further additional steps shall be taken to ensure it, such as counterweights, anchorages and buttresses for example.

Table 4. **Safety factor against overturning, sliding and lifting**

	Loading *)	ν
1	Favourably acting proportions of the dead load	1,0
2	Unfavourably acting proportions of the dead load	1,1
3	Unfavourably acting wind loads	1,2
4	Unfavourably acting proportions of loads other than the loads listed in items 2 and 3	1,3

*) If loads are resolved into components, then these components shall be multiplied by the same value of ν.

6.1.1 The safety against overturning shall be calculated from:

$$\Sigma \nu \cdot M_{St} \geq \Sigma \nu \cdot M_K \tag{81}$$

where

ν is the safety factor in accordance with table 4;

M_{St} are the stability moment proportions;

M_K are the overturning moment proportions.

Care shall be taken to ensure that the loads entered in the calculation are capable of being activated over the shear stiffness of the structure.

6.1.2 The safety against sliding shall be calculated from:

$$\Sigma \nu \cdot \mu \cdot N \geq \Sigma \nu \cdot H \tag{82}$$

where

ν is the safety factor in accordance with table 4;

N is the vertical load component;

H is the horizontal load component;

μ is the coefficient of friction in accordance with table 5.

The following coefficients of friction may be assumed for the determination of the frictional forces, unless higher values determined by tests are available in individual cases, or unless moisture dictates the adoption of lower values:

Table 5. **Coefficients of friction**

	Wood	Steel	Concrete
Wood	0,4	0,4	0,6
Steel	0,4	0,1	0,2
Concrete	0,6	0,2	0,5
Clay *)	0,25	0,2	0,25
Loam *)	0,4	0,2	0,4
Sand and gravel	0,65	0,2	0,65

*) In stiff plastic state in accordance with DIN 1054 at the very least.

It shall be borne in mind that loosening by vibration may occur in the case of supports subjected to vibratory stress.

If a ν-fold safety factor in the ground joint is not attained by static friction alone when the structure is anchored in the ground, then the safety against sliding shall be verified in conjunction with the action of soil anchors. In this context, the coefficients of friction in accordance with table 5 shall only be entered in the calculation at 70 % of the listed values.

$$\Sigma \nu \cdot \bar{\mu} \cdot N + Z_h \geq \Sigma \nu \cdot H \tag{83}$$

$$\bar{\mu} = 0{,}7 \cdot \mu \tag{84}$$

where

Z_h is the transmittable horizontal component of the anchor.

6.1.3 Safety against lifting shall be calculated from:

$$\Sigma \nu \cdot N_{St} \geq \Sigma \nu \cdot N_a \tag{85}$$

where

ν is the safety factor in accordance with table 4;

N_{St} are the vertical stabilizing load components;

N_a are the vertical lifting load components.

With anchor ties we have the following relationship:

$$\Sigma \nu \cdot N_{St} + Z_v \geq \Sigma \nu \cdot N_a \tag{86}$$

where

Z_v is the transmittable vertical component of the anchor.

6.1.4 For foundations DIN 1054 shall apply, in addition to subclause 6.1.

6.2 Ground anchorages

6.2.1 Loadbearing capacity of anchors

6.2.1.1 General

Uncertain soil conditions and the type of loading make it extremely difficult to assess the loadbearing capacities of anchorages by calculation. The information will therefore be restricted to

weight anchors, i.e. ballast bodies placed on the surface of the ground or buried, and

bar anchors, i.e. metal or wooden bars fitted with eyelets or with an upset head.

As regards special anchors such as wing anchors, folding anchors, screw anchors and sectional steel anchors for example, the determination of their loadbearing capacities shall be effected by means of test loadings.

6.2.1.2 Weight anchors

When calculating the loadbearing capacity of these anchors, the passive earth pressure shall only be taken into account on condition that the anchor is capable of performing small displacements and twists without any danger to the structure, and that the foundation soil conditions are sufficiently known.

6.2.1.3 Bar anchors

The loadbearing capacity of single bar anchors with a circular cross section and with a minimum driving-in depth of 80 cm shall be determined in accordance with the following approximation formulae:

For $\beta = 0°$ for stiff cohesive and for tightly compact non-cohesive soils (see DIN 1054):

$$Z = 6{,}5 \cdot d \cdot l' \tag{87}$$

for semi-solid cohesive soils (see DIN 1054):

$$Z = 8 \cdot d \cdot l' \tag{88}$$

For $\beta \geq 45°$ for at least stiff plastic cohesive soils (see DIN 1054):

$$Z = 10 \cdot d \cdot l' \quad (89)$$

for tightly compact non-cohesive soils (see DIN 1054):

$$Z = 17 \cdot d \cdot l' \quad (90)$$

For $0° < \beta < 45°$ the loadbearing capacity for the above soil types shall be determined by interpolation (see figure 15).

In formulae (87) to (90)

Z is the loadbearing capacity of anchor (failure load), in N;

Z_h is the horizontal component of loadbearing capacity of anchor, in N;

Z_v is the vertical component of loadbearing capacity of anchor, in N;

d is the anchor diameter, in cm;

l' is the driving-in depth, in cm;

α is the driving-in angle;

β is the angle of pull.

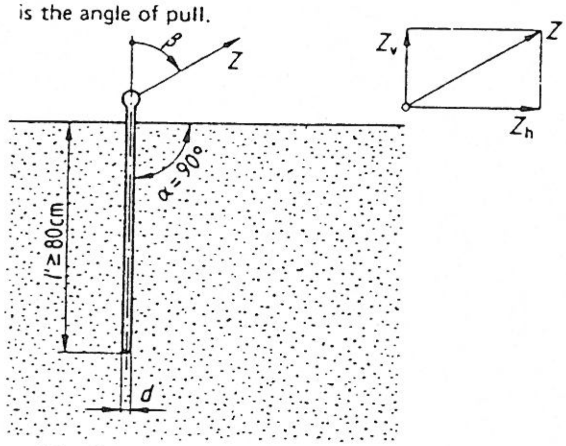

Figure 14. Bar anchor

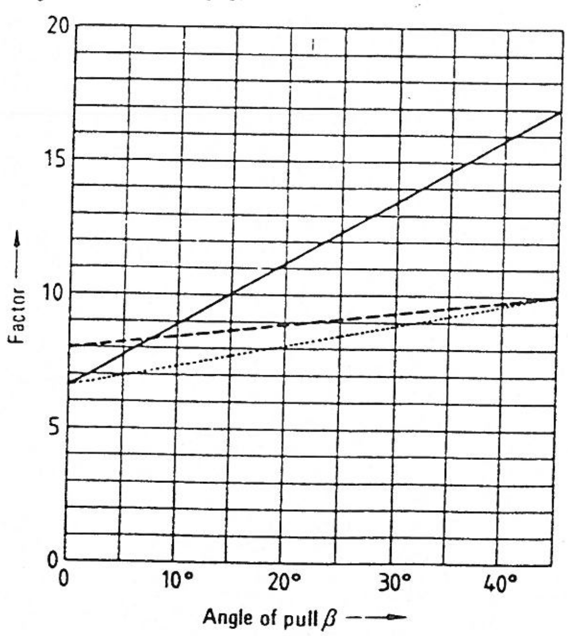

Figure 15. Factor for determining the loadbearing capacity of bar anchors

————	tightly compact non-cohesive soils
– – – –	semi-solid cohesive soils
....	stiff plastic cohesive soils

Formulae (87) to (90) are only valid on the condition that the anchor will "pull" when driven in. For $\beta = 0°$, the friction shall be effective along the entire length of the bar; for $\beta \geq 45°$, the driving-in angle α shall be 90°. At this driving-in angle, the obliquely loaded anchor will attain its maximum loadbearing capacity, as proved by experience.

The calculated loadbearing capacities may be exceeded, if this can be substantiated by test loadings, or if experimental data relating to the installation site are available.

As regards test loadings on anchors, at least three tests shall be carried out. The lowest test value shall be the determining one for the evaluation of the loadbearing capacity. The loadbearing capacity determined in this manner shall not result in any anchor movement which would be inadmissible for the structure.

The safety coefficients featured in table 4 shall be taken into consideration when determining the permissible loadbearing capacity.

If the foundation conditions are comparable, test loadings carried out in another location may be adduced for substantiation purposes.

In order to prevent any bending of anchors subjected to oblique traction, the following minimum diameter should be aimed at for single round steel bar anchors:

$$d_{min} = 0{,}025 \cdot l' + 0{,}5 \text{ (with } l' \text{ in cm)} \quad (91)$$

The point of application of the force on bar anchors subjected to bending stress shall be situated as close to the ground surface as possible, or beneath it.

6.2.1.4 Force to be anchored and safety factor

The required anchorage force erf Z_ν shall be determined by vector addition of the ν-fold load components which can be allotted to the anchor.

$$\text{erf } \bar{Z}_\nu = \Sigma\nu \cdot \bar{Z} \leq Z \quad (92)$$

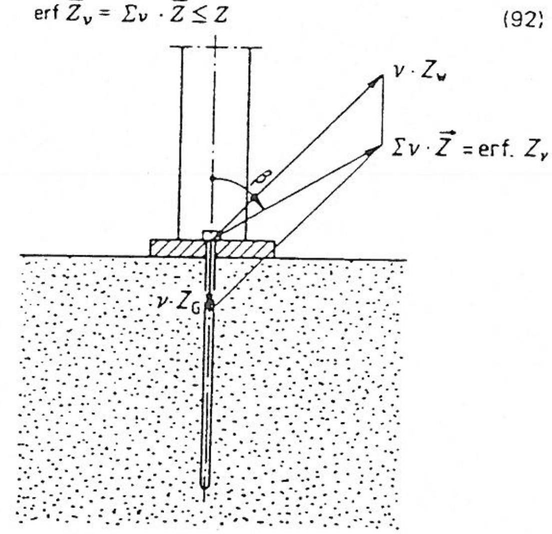

Figure 16. Anchor loadings

In figure 16

Z_G is the favourably acting proportion of self weight;

Z_W is the unfavourably acting proportion of wind loads or other loads;

ν is the safety factor in accordance with table 4.

6.2.2 Recommendations

If displacements in excess of 2 cm occur on loaded bar anchors or similar devices, then the loadbearing capacity of the anchor will no longer be fully ensured. An increased load absorption can be achieved by means of additional anchorages or by driving in wood wedges.

In the case of pure unadulterated tensile stress in the direction of the axis of the bar anchor, the danger of a complete failure of the anchor already arises when very small movements occur.

The foot of the anchor (pointed tip) shall not exhibit any widening of the cross section in the case of bar anchors, so as not to cause any reduction of the skin friction in the zone of the anchor shank.

After the driving in of a bar anchor, the soil on the surface shall be tamped against the anchor, as far as practicable, in order to prevent the infiltration of surface water.

If groups of anchors are used, each individual anchor may only be assessed in the calculation at its full calculated loadbearing capacity on condition that the spacings between adjoining anchors amount to not less than five times the anchor diameter.

Dynamic loads can lead to the loosening of an anchorage; consequently, repeated checks of the anchors are essential.

6.3 Timber packings

Only very low ground pressures apply to timber packings, because of the absence of embedment in the soil and of the relatively small bearing widths in practice. Timber packings are liable to press themselves into the soil and cause considerable settlements.

Timber packings shall be kept under observation in the case of excessively yielding soils; in the event of yielding or loosening, an underlay shall be provided and the bearing surfaces shall be enlarged if necessary.

For a foundation soil with a low loadbearing capacity, additional measures shall be adopted. If several elements are laid side by side without any gaps in order to increase the bearing widths, an interconnection shall be created, e.g. by cross stacking.

For a foundation soil which can be travelled over, the following permissible soil pressures may be entered in the calculation for square and rectangular (length : width ≤ 3) timber packings as a function of the bearing width:

b = 20 cm: zul σ = 100 kN/m^2;

b = 30 cm: zul σ = 150 kN/m^2;

b = 40 cm: zul σ = 200 kN/m^2.

For hard (paved) erection locations, higher permissible soil pressures may be considered.

7 Verification of strength

7.1 General

A distinction shall be made between predominantly static stress and predominantly vibrating stress. Vibrating stress occurs both in the form of pulsating stress (stress which fluctuates within two limiting values without any change of sign, min σ/max $\sigma \geq 0$) and in the form of alternating stress (stress which fluctuates between two limiting values and changes its sign when so doing, min σ/max $\sigma < 0$).

Structures subjected to vibrating stress which are likely to be exposed to more than 2×10^4 reversals of stress (stress cycles) from pulsating stress or alternating stress during their expected service life shall be dimensioned in respect of fatigue strength under vibrating stresses.

In this context, the fatigue strength σ_D is understood to be the stress which a test bar can only just withstand without fracturing when it is subjected to an ultimate number of stress cycles N_G of 2×10^6 stress cycles (in the case of steel structures) or 10^7 stress cycles (in the case of machinery).

7.2 Predominantly static stress

The existing dimensional standards (e.g. DIN 18800 Part 1, DIN 1052 Part 1, DIN 4113 Part 1) for the material concerned shall be determining as regards the permissible stresses of structural components.

As regards the general stress analysis for machinery components made of steel, including components which act simultaneously as structural components, the following relationship shall apply:

$$\text{zul}\ \sigma = \frac{\beta_B}{\nu_B} \quad \text{or} \quad \frac{\beta_{0.2}}{\nu_{0.2}} \tag{93}$$

The smaller of the two values above shall be decisive.

Table 6. Safety factor

		In respect of β_B	In respect of $\beta_{0.2}$ *)
Loading case	H	37/16	24/16
	HZ	37/18	24/16

*) In the case of a corresponding specification in the material standards, β_S shall count as $\beta_{0.2}$.

For shear resulting from transverse force and torsion, the following relationship shall apply:

$$\text{zul}\ \tau = 0{,}65\ \text{zul}\ \sigma \tag{94}$$

7.3 Vibrating stress

7.3.1 Fatigue strength of building structures

The fatigue strength of building structures in St 37-2 or St 52-3 steel shall be verified in accordance with DIN 15018 Part 1 or DIN 4132, in accordance with the operating groups specified in these standards, and with notch cases for loading case H.

In the verification of operating strength all permissible stresses are subject to an upper limitation, viz. the limitation given by the permissible stresses of loading case HZ of the general stress analysis in accordance with DIN 15018 Part 1, April 1974 edition, subclause 7.2.1, tables 10 to 12. As regards compression stresses in structural components, the values of the zul σ_Z column shall apply.

If no accurate verification is carried out, operating group B6 shall be used for the calculation.

In this connection, the values in accordance with DIN 15018 Part 1 may be increased by up to 20 % for zul σ_D under the following conditions:

a) These structural components or zones of structural components shall be capable of being inspected in respect of freedom from cracks. As a general rule, a visual examination will suffice.

b) These structural components shall be prominently featured in the structural engineering documents, with an exact description of the zones concerned, and if necessary they shall be clearly listed.

c) These components or zones shall be specially checked during each inspection preceding the renewal of the construction authorization.

The increase of the permissible stresses by 20 % includes a 1,1-fold safety at 90 % survival probability (see also DIN 15 018 Part 1, April 1974 edition, subclause 7.4.4).

Load increase factors in accordance with subclause 4.4 need only be entered in the calculation for the structural component zones concerned.

7.3.2 Fatigue strength of machine components

7.3.2.1 Determination of tolerable stress

As regards materials not listed in DIN 15 018 Part 1, and as regards cases not treated in that standard (e.g. machine components) the determination of the tolerable stresses in the case of vibrating stress can be carried out in accordance with one of the calculation methods featured in [1] to [6].

In this context, the following influences shall be taken into account:

a) fatigue notch factor;

b) influence of size;

c) influence of surface;

d) cross-sectional shape;

e) if applicable, anisotropy coefficient.

7.3.2.2 Determination of existing stresses

The existing stresses in the structural component (nominal stresses) shall be determined in accordance with the general principles of stress analysis.

7.3.2.3 Safety factor

The actual safety of the structural component against fatigue failure is:

a) for pure tensile, bending or torsional stress:

$$\text{vorh}\ \nu = \frac{\sigma_{AG}}{\sigma_a} \quad \text{or} \quad \frac{\tau_{AG}}{\tau_a} \tag{95}$$

b) for compound stress:

$$\text{vorh}\ \nu = \frac{\sigma_{AG}}{\sigma_{av}} \tag{96}$$

c) against overstepping of the yield point or elastic limit:

$$\text{vorh}\ \nu = \frac{\sigma_{SG}}{\sigma_a + \sigma_m} \quad \text{or} \quad \text{vorh}\ \nu = \frac{\sigma_{SG}}{\sigma_{av} + \sigma_{mv}} \tag{97}$$

where

σ_{AG} is the amplitude strength of the structural component dependent on shape;

σ_{SG} is the yield point (elastic limit) of the strength dependent on shape;

σ_a is the alternating stress amplitude;

σ_m is the mean stress;

σ_{av} is the comparison alternating stress amplitude;

σ_{mv} is the comparison mean stress.

Universally binding safety factors erf ν are not capable of being specified with absolute precision. They are governed by the number and weight of uncertainty factors and by the possible consequences in the event of failure. The greater the deformability of the material, the lower the safety factor that can be selected.

If reliable data on the actually prevailing stress conditions are available, a value for erf ν situated between 1,2 and

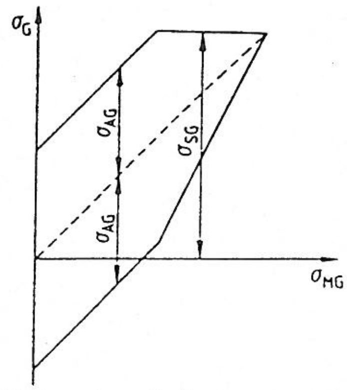

Figure 17. Fatigue strength diagram according to Smith, for strength dependent on shape

1,5 will suffice, for material parameters σ_D on the basis of 90 % survival probability.

Safety factors up to 2,5 are usual for machinery calculations in respect of fatigue strength, in the case of data which are in part estimated. In all cases, the following relationship shall be given:

$$\text{vorh}\ \nu \geq \text{erf}\ \nu \tag{98}$$

7.4 Bolts

DIN 18 800 Part 1 shall apply for bolts conforming to DIN 931 Part 1, DIN 7968 and DIN 7990 assigned to property classes 4.6 and 5.6.

DIN 18 800 Part 1 shall also apply for high strength bolts conforming to DIN 6914 to DIN 6918 assigned to property class 10.9.

In deviation therefrom, the following shall apply for bolts assigned to the property classes referred to below.

a) Screwed connections with bolts subjected to tensile stress may be designed with a bolt hole clearance of 1,0 mm even in the case of vibrating stress, if the forces normal to the axis of the bolt are absorbed by the provision of dogs, pins, cotter pins, bushes etc, or if a calculation in respect of friction contact is carried out with a friction coefficient of $\frac{2}{3} \cdot \min \mu$.

The value to be adopted for min μ shall be the lowest coefficient of friction occurring in operation under the most unfavourable conditions.

b) In the case of single-shear joints, the eccentricity shall be taken into consideration.

The following shall apply for bolts assigned to property classes 6.9, 8.8 and 10.9:

1. permissible shear stresses in accordance with table 7;
2. permissible calculated pressure on the face of the bolt hole for shear bearing pressure joints in accordance with DIN 18 800 Part 1, March 1981 edition, table 7, for non-prestressed bolts;
3. permissible additional transmissible tensile force in the direction of the bolt axis per prestressed bolt or fitted bolt in accordance with table 9; in this context, F_V in accordance with table 8;
4. permissible prestressing forces and tightening torques in accordance with table 8;
5. as regards the fatigue strength, guideline values for the alternating stress amplitude are given in table 10, on the assumption that the sum of the mean stress plus the alternating stress amplitude does not exceed β_S.

Bolts may be used again on condition that they have not been stressed beyond the yield point.

The listed values are valid for an overall friction coefficient ges μ = 0,14 (dry to slightly lubricated) making use of 90 % of the minimum yield point.

Table 7. **Permissible shear stresses τ_a for a predominantly static stress per bolt, and for a shearing area perpendicular to the axis of the bolt**

Property class	6.9		8.8		10.9	
Loading case	H	HZ	H	HZ	H	HZ
zul τ_a N/mm²	145	160	200	230	240	270

Table 8. **Permissible prestressing forces and tightening torques for bolts**

Thread size	Permissible prestressing force F_V (kN) for property class			Permissible tightening torque M_a (Nm) for property class		
	6.9	8.8	10.9	6.9	8.8	10.9
M 8	14	16	23	21	25	35
M 10	22	26	37	41	49	69
M 12	31	37	50	70	84	120
M 16	60	71	100	176	206	350
M 20	94	111	160	338	402	600
M 22	116	138	190	456	539	900
M 24	135	160	220	588	696	1100
M 27	177	210	290	873	1030	1650
M 30	216	257	350	1177	1422	2200
M 33	275	326	459	1668	1977	2784
M 36	323	382	510	2134	2524	3340

Table 9. **Permissible additional transmissible tensile force zul Z in the direction of the bolt axis, per prestressed bolt**

Predominantly static stress for loading case		Vibrating stress for loading case	
H	HZ	H	HZ
0,7 F_V	0,8 F_V	0,6 F_V	0,7 F_V
F_V in accordance with table 8.			

Table 10. **Guideline values for the permissible alternating stress amplitude of commercial grade bolts**

Thread size	Alternating stress amplitude $\pm\sigma_A$ N/mm² for property classes	
	3.6 to 5.6	5.8 to 10.9
M 12 – M 16	45	50
M 20 – M 36	40	40

7.5 Ropes, chains, safety devices, rope drives, connectors and adapters

7.5.1 Standards relating to ropes, chains, safety devices, rope drives, connectors and adapters

When ropes, chains, safety devices, rope drives, connectors and adapters are used, the following standards in particular shall be observed.

Wire ropes	– DIN 3051 to DIN 3071
natural fibre ropes	– DIN 83 305 Part 1 to Part 3; DIN 83 322, DIN 83 324, DIN 83 325
synthetic material ropes	– DIN 83 330 to DIN 83 332
chains	– DIN 685 Part 2; DIN 766; DIN 5686; DIN 5687 Part 1 and Part 3; DIN 8187; DIN 32 891
clamps for wire ropes	– DIN 1142
rope drives	– DIN 15 020 Part 1 and Part 2
eye hooks	– DIN 7540
spring safety hooks	– DIN 5299
roller buckles	– DIN 5291
shackles	– DIN 82 101
safety harnesses; safety ropes	– DIN 7471
turnbuckles	– DIN 1478; DIN 1480

7.5.2 Ropes, chains, belts, straps –

7.5.2.1 Permissible loadbearing capacity of ropes, chains, belts, straps

The permissible loadbearing capacity will depend on the intended application. The following relationship shall apply:

$$\text{Permissible load-bearing capacity} = \frac{\text{Minimum load at fracture}}{\text{Serviceability factor}} \qquad (99)$$

7.5.2.2 Suspensions of structural components loaded with passengers (e.g. chairs, gondolas)

For steel chains, the serviceability factor is 6.

As regards steel wire ropes, the values given in table 11 shall apply.

The use of ropes, chains, belts or straps made of hemp, plastics or leather is not permitted for these applications. This does not apply however to safety equipment in accordance with subclause 7.5.4.

Table 11. **Permissible stresses for guy ropes and stay ropes made from individual wires of 1570 N/mm² nominal strength, for the purpose of verification of operating strength**

Diameter of wire rope mm	Permissible stress zul σ_{Dz}, in N/mm², for loading groups B1, B2 and B3	B4, B5 and B6
*) up to 5	450	400 + 50 · x
over 5 up to 20	350 + 100 · x	250 + 200 · x
over 20 up to 30	300 + 150 · x	200 + 250 · x
over 30 up to 40	250 + 200 · x	150 + 300 · x

*) For design reasons, wire rope diameters smaller than 4 mm shall be avoided.

$$x = \frac{\min \sigma}{\max \sigma}.$$

7.5.2.3 Guy ropes, stay ropes, anchoring ropes and chains

7.5.2.3.1 For predominantly static stress, 4 is the serviceability factor for steel chains.

For wire ropes made from individual wires with a nominal strength of 1570 N/mm^2 the permissible stress in the metal cross section shall be taken as zul σ = 450 N/mm^2 for the general stress analysis.

As regards fibre ropes made from natural and/or synthetic fibres, the values given in table 12 shall apply.

Table 12. Serviceability factors

Rope diameter mm	Serviceability factor
12	6
14	5
16	5
18	4
20 and thicker	4

7.5.2.3.2 For predominantly vibrating stress DIN 15 018 Part 1 shall apply for the verification of the operating strength of ropes made from individual wires with a nominal strength of 1570 N/mm^2, and for rope fastenings.

Wire rope diameters smaller than 4 mm shall be avoided for temporary structures.

Rope clamps shall not be used for fastenings onto driving mechanisms and safety devices.

If individual wires with a nominal strength exceeding 1570 N/mm^2 are used, the permissible stress shall be assessed separately. An increase of the permissible stress values specified in DIN 15 018 in relation to the nominal strengths shall not be effected just as a matter of course.

For steel chains, the serviceability factor is 6.

7.5.2.4 Ropes shall not be used any longer under the following circumstances:

- if a strand breaks;
- if the rope kinks;
- if there is evidence of serious mechanical damage or of severe wear; serious mechanical damage of fibre ropes shall be deemed to exist, if more than 10 % of the total number of rope yarns in the most seriously damaged cross section of the rope are broken;
- if fibre dust drops out of the rope;
- if the rope rots;
- if splices become slack;
- if appreciably large molten patches are present on ropes made from synthetic fibres.

Repaired ropes shall not be used; the shortening of ropes does not count as a repair.

The repair of splices is not permitted.

7.5.3 Rope drives

Rope drives fitted with synthetic material ropes may be used in cases where passengers will not be exposed to any immediate danger when a rope breaks.

7.5.4 Safety devices

A serviceability factor of 6 shall be adopted for safety devices, e.g. locking devices of gondolas or chairs, safety belts, safety harnesses in loop the loop-the-loop swings.

7.5.5 Connectors and adapters

7.5.5.1 The hooks and eyelets of turnbuckles are not standardized. Their permissible loading shall be determined with the aid of the serviceability factors for steel chains (4 or 6) in accordance with subclause 7.5.2.1.

7.5.5.2 The permissible loadings in accordance with DIN 82 101 may be trebled for statically stessed shackles. DIN 82 101 shall apply to dynamically stressed shackle connections. The shackle pins shall be secured against loosening.

7.5.5.3 As regards the foot strap buckles in loop-the-loop swings, the following sizes shall be adopted for roller buckles in accordance with DIN 5291:

steel buckles: size b not less than 25 mm;

AlMgSi buckles: size b not less than 30 mm.

8 Structural design and workmanship

8.1 Arrangement, accessibility

8.1.1 Structural components which are sized in accordance with subclause 7.3.1 with stresses increased by 20 % in comparison with DIN 15 018 Part 1, shall be accessible for the necessary checks at least in the dismantled condition.

8.2 Locking and safety devices

8.2.1 Bolts, nuts, wedges and other fasteners, the slackening of which, as a result of vibrating stresses, might result in accidents, shall be secured.

On fully prestressed bolts, the prestressing counts as security against slackening.

However, because even fully prestressed screwed connections are liable to slacken, particularly in the initial stages as a result of settlement, e.g. in the case of ball bearing slewing gear, reference shall be made in the erection and operating instruction manual to the necessary checks to be carried out.

8.3 Disconnectable joints

8.3.1 Spring washers, toothed lock washers, fan type (serrated) lock washers and similar locking devices are not permitted on screwed connections fitted with bolts assigned to property class 8.8 or higher.

8.3.2 Open hooks are not permitted on wind bracings. In so far as their use cannot be avoided in other cases, they shall be curved in the hot condition or forged. If there is a possibility of their becoming unintentionally unhooked, they shall be fitted with a safety catch.

8.3.3 Drilled holes in timber components for connecting bolts which are subjected to alternating and pulsating loads, or on which the bolts are regularly removed during erection and dismantling operations, shall be relieved from stress by the provision of steel fishplates or dowel pins.

Tensile forces in drilled holes acting at right angles to, or obliquely to the direction of the grain, which might lead to the splitting or tearing of the wood, shall be absorbed by closed tires on either side of the drilled holes, or by other suitable means. Bolts which are not protected by flat steel bars shall be provided with washers. If compression forces are transmitted from the bolts onto the wood, the washers shall be sized in respect of the forces which arise.

As a general rule, it shall be borne in mind that any appreciable weakening of timber cross sections shall be avoided. This applies in particular to timbers exposed to impacts, or subjected to alternating or pulsating stresses. Insert dowel pins shall not be removed from the wood.

8.3.4 Rope connections shall be formed in such a way that there is no possibility of kinks or knots arising, or of excessive stressing of individual wires.

8.3.5 Stay ropes made of hemp may be knotted. The knots shall however be frictionally locking, i.e. knots which tighten under load.

8.3.6 Ropes of any kind shall not rest against sharp edges.

8.4 Welded joints

Welded steel structural components which are subjected to frequently recurring stresses (operating strength) may only be manufactured in workshops which can submit proof of their suitability to carry out such work. This proof shall be deemed to have been adduced if the comprehensive certificate of suitability in accordance with DIN 18 800 Part 7, together with the extension for DIN 4112 is submitted.

As regards the submission of proof for the suitability for welding structural components subject to predominantly static loads, DIN 18 800 Part 7 shall also apply.

8.5 Shaping and designing of components subject to vibrating loads

Abrupt transitions in cross section (sudden jumps in stiffness) and notches shall be avoided in components subject to vibrating stresses.

8.6 Supports

Jack screws (pot jacks and the like) which transmit loads into the surface of the ground shall if necessary be cross-braced against one another if pendulum stanchions are created when the spindles are fully extended.

8.7 Central masts

Central masts for the rotating components of roundabouts shall not be made of wood.

8.8 Brakes

8.8.1 All parts of moving or amusement installations which are in motion during normal operation shall be capable of being safely braked for the benefit of the users. The brakes shall be constructed in such a way that operating safety is ensured and that stability is not put at risk. Consequently the brakes shall not lock or jam and they shall act sufficiently progressively for the retardation to be bearable for the passenger (see subclause 5.5.4).

8.8.2 Stopping brakes and slowing-down brakes shall be designed to withstand fatigue stress.

8.9 Bracings, stiffenings

8.9.1 Stiffening bracings (wind bracings)

See subclause 5.17.3.3.

8.9.2 It may become necessary for certain structures to require special additional structural measures for the reduction or attenuation of inadmissible vibrations (e.g. resonance).

8.10 Protection against corrosion, surface protection, protection against rot

8.10.1 See DIN 55 928 Part 1 to Part 9 for steel components.

8.10.2 See DIN 4113 Part 1 for light alloy components.

8.10.3 See DIN 1052 Part 1 for timber components.

8.11 Passenger seats, passenger cabin [3)]

When sizing and designing the passenger seats and passenger cabins, due attention shall be paid to an adequate height and to the upholstering of the back rests and arm rests and also to support and holding facilities and to safety devices.

8.12 Ball bearing slewing rims

In order to achieve satisfactory running conditions, it will be necessary for the connection structures both above and below the bearing to be rigid. Any distortion or warping of the ball bearing slewing rims shall be avoided.

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3) Meier, K. *Sicherheit Fliegender Bauten* (Safety of temporary structures), published by *TÜV Bayern e. V.*, München.

Standards referred to and other documents

DIN	685 Part 2	Tested round steel chains; safety requirements
DIN	766	Round steel chains for general purposes and for hoisting equipment; tested short-linked chains in fixed length
DIN	931 Part 1	M 1,6 to M 39 hexagon head bolts with shank; product grades A and B (modified version of ISO 4014)
DIN	1050	Steel in building construction; calculation and constructional design
DIN	1052 Part 1	Timber structures; calculation and construction
DIN	1054	Subsoil; permissible loading of subsoil
DIN	1055 Part 1	Design loads for buildings; stored materials, building materials and structural members, dead load and angle of friction
DIN	1055 Part 2	Design loads for buildings; soil characteristics; specific weight, angle of friction, cohesion, angle of wall friction

DIN 1055 Part 4	Design loads for buildings; live loads; wind loads of structures unsusceptible to vibration
DIN 1055 Part 5	Design loads for buildings; live loads; snow load and ice load
DIN 1080 Part 1	Concepts, symbols and units used in civil engineering; principles
DIN 1142	Wire rope grips for rope terminations to meet safety requirements
DIN 1478	Turnbuckles made from steel tube or round steel bar
DIN 1480	Open-type forged turnbuckles
DIN 1629 Part 1	Seamless tubes in unalloyed steels for supply purposes, process plant and tanks; survey, technical delivery conditions, general data
DIN 1681	Steel castings for general use; quality specifications
DIN 3051 Part 1	Steel wire ropes; characteristics, survey
DIN 3051 Part 2	Steel wire ropes; characteristics, types of ropes, concepts
DIN 3051 Part 3	Steel wire ropes; characteristics, calculation, factors
DIN 3051 Part 4	Steel wire ropes; characteristics, technical delivery conditions
DIN 3052	Steel wire ropes; 1 X 7 spiral rope
DIN 3053	Steel wire ropes; 1 X 19 spiral rope
DIN 3054	Steel wire ropes; 1 X 37 spiral rope
DIN 3055	Steel wire ropes; 6 X 7 round strand rope
DIN 3056	Steel wire ropes; 8 X 7 round strand rope
DIN 3057	Steel wire ropes; Filler 6 X 19 round strand rope
DIN 3058	Steel wire ropes; Seale 6 X 19 round strand rope
DIN 3059	Steel wire ropes; Warrington 6 X 19 round strand rope
DIN 3060	Steel wire ropes; Standard 6 X 19 round strand rope
DIN 3061	Steel wire ropes; Filler 8 X 19 round strand rope
DIN 3062	Steel wire ropes; Seale 8 X 19 round strand rope
DIN 3063	Steel wire ropes; Warrington 8 X 19 round strand rope
DIN 3064	Steel wire ropes; Warrington-Seale 6 X 36 round strand rope
DIN 3065	Steel wire ropes; Warrington compound 6 X 35 round strand rope
DIN 3066	Steel wire ropes; Standard 6 X 37 round strand rope
DIN 3067	Steel wire ropes; Warrington-Seale 8 X 36 round strand rope
DIN 3068	Steel wire ropes; Standard rope + 7 fibre inserts, 6 X 24 round strand rope
DIN 3069	Steel wire ropes; non-rotating 18 X 7 spiral round strand rope
DIN 3070	Steel wire ropes; non-rotating 10 X 10 flattened strand rope
DIN 3071	Steel wire ropes; rotation-free 36 X 7 spiral round strand rope
DIN 4113 Part 1	Aluminium structures subject to predominantly static loading; calculation and structural design
DIN 4132	Craneways; steel structures, principles for calculation, design and construction
DIN 5291	Roller buckles
DIN 5299	Spring safety hooks of half-round wire rod, round wire rod or forged
DIN 5686	Gusset chains without quality requirements
DIN 5687 Part 1	Non-calibrated and tested round steel link chains; grade 5
DIN 5687 Part 3	Non-calibrated and tested round steel link chains; grade 8
DIN 6914	Hexagon bolts with large widths across flats for high-tensile bolting in steel structures
DIN 6915	Hexagon nuts with large widths across flats for high-tensile bolting in steel structures
DIN 6916	Washers, round, for high tensile bolting in steel structures
DIN 6917	Washers, square, for high-tensile bolting of I-sections in steel structures
DIN 6918	Washers, square, for high-tensile bolting of channels in steel structures
DIN 7471	Safety harnesses; lanyards
DIN 7540	Eye hooks, quality grade 5
DIN 7968	Hexagon fit bolts, without nut and with hexagon nut for steel structures
DIN 7990	Hexagon bolts with hexagon nuts for steel structures
DIN 8187	Roller chains, European type
DIN 15018 Part 1	Cranes; principles for steel structures, stress analysis
DIN 15020 Part 1	Lifting appliances; principles relating to rope drives, calculation and construction
DIN 15020 Part 2	Lifting appliances; principles relating to rope drives, inspection during operation
DIN 17100	Steels for general structural purposes; quality standard
DIN 17200	Quenched and tempered steels; quality specifications

DIN 17 210	Case hardening steels; quality specification
DIN 18 800 Part 1	Steel structures; design and construction
DIN 18 800 Part 7	Steel structures; manufacture, verification of suitability for welding
DIN 32 891	Non-calibrated and tested round steel link chains; grade 2
DIN 55 928 Part 1	Corrosion protection of steel structures by organic and metallic coatings; general
DIN 55 928 Part 2	Corrosion protection of steel structures by organic and metallic coatings; corrosion-proof design of steel structures
DIN 55 928 Part 3	Corrosion protection of steel structures by organic and metallic coatings; planning of corrosion protection
DIN 55 928 Part 4	Corrosion protection of steel structures by organic and metallic coatings; preparation and testing of surfaces
DIN 55 928 Part 5	Corrosion protection of steel structures by organic and metallic coatings; coating materials and protective systems
DIN 55 928 Part 6	Corrosion protection of steel structures by organic and metallic coatings; execution and inspection of corrosion protection work
DIN 55 928 Part 7	Corrosion protection of steel structures by organic and metallic coatings; technical rules relating to reference surfaces
DIN 55 928 Part 8	Corrosion protection of steel structures by organic and metallic coatings; corrosion protection of loadbearing thin-walled structural members (lightweight steel structures)
DIN 55 928 Part 9	Corrosion protection of steel structures by organic and metallic coatings; binders and pigments for coating materials
DIN 82 101	Shackles
DIN 83 305 Part 1	Fibre ropes; synopsis
DIN 83 305 Part 2	Fibre ropes; concepts, parameters, design values, structure, types
DIN 83 305 Part 3	Fibre ropes; technical delivery conditions
DIN 83 322	Manila ropes, quality grade 1
DIN 83 324	Sisal ropes
DIN 83 325	Hemp ropes
DIN 83 330	Polyamide ropes
DIN 83 331	Polyester ropes
DIN 83 332	Polypropylene ropes
DIN ISO 898 Part 1	Mechanical properties of fasteners; bolts, screws and studs

[1] Hänchen, R., Decker, K. H. *Neue Festigkeitslehre* (New theory of strength of materials), *Carl Hanser Verlag*, München.

[2] DDR-Standard TGL 19 340 Sheet 1 to Sheet 4, *Buchhaus Leipzig, Abt. Standards*, DDR-701 Leipzig 1, Postfach 140.

[3] Wellinger–Dietmann *Festigkeitsberechnung* (Stress analysis), *Alfred Kröner Verlag*, Stuttgart.

[4] Tauscher, H. *Dauerfestigkeit von Stahl und Gusseisen* (Fatigue strength of steel and cast iron), *Archimedes Verlag*, Kreuzlingen/Schweiz.

[5] Laszlo Sors. *Berechnung der Dauerfestigkeit von Maschinenteilen* (Calculation of fatigue strength of machinery components. Published by the Hungarian Science Academy Publications Dept., Budapest.

[6] *VDI-Richtlinie* (Code of practice) 2226, 2227

Further relevant standards and other documents

DIN 4114 Part 1	Steel structures; stability cases (buckling, overturning, bulging), design principles, rules
DIN 4114 Part 2	Steel structures; stability cases (buckling, overturning, bulging), design principles, guidelines
DIN 4115	Lightweight and tubular steel construction in building; rules for approval, construction and design
DIN 18 808	(at present at the stage of draft) Steel structures; loadbearing structures made from hollow sections, under predominantly static stress

Directives relating to the construction and operation of temporary structures [4)]

Previous editions

Supplement to DIN 4112: 10.62, DIN 4112: 05.38x, 03.60

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4) Published by *ARGEBAU*; reprinted in the Official Ministerial Gazette of each *Land* of the German Federal Republic.

Amendments

As compared with the March 1960 edition and with the supplement to DIN 4112, October 1962 edition, the following amendments have been made:

The content has been completely revised. New structures and travelling installations have been incorporated in the standard; new calculation methods have been adopted, calculation formulae changed and complemented; rulings for roofing-over structures have been specified; the verification of safety against overturning, sliding and lifting-off has been specified according to new rules; specifications have been made for the calculation of the loadbearing capacity of anchors; rules have been laid down in respect of vibrating loads to which building structures and machinery components are subjected; this complete revision has made obsolete the October 1962 edition of the supplement to DIN 4112.

International Patent Classification

A 63 G