Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 2501 (2010-11)

Structural Waterproofing in Nuclear Power Plants

(Bauwerksabdichtungen in Kernkraftwerken)

The previous versions of this Safety Standard were issued in 2004-11, 2002-06 and 1988-09.

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

Editor:

KTA-Geschaeftsstelle c/o Bundesamt fuer Strahlenschutz (BfS)
Willy-Brandt-Str. 5 • 38226 Salzgitter • Germany
Telephone +49 3018 333-0 • Telefax +49 3018 333-1625

KTA SAFETY STANDARD

2010-11	**Structural Waterproofing in Nuclear Power Plants**	KTA 2501

Previous versions of this safety standard: 1988-09 (BAnz. No. 37a of February 22, 1989)
2002-06 (BAnz. No. 172a of September 13, 2002)
2004-11 (BAnz. No. 133a of February 16, 2004

Contents

Comments by the Editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Fundamentals

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to attain the protective goals specified in AtG and the Radiological Protection Ordinance (StrlSchV) and further detailed in the "Safety Criteria" and in the “Design Basis Accident Guidelines”.

(2) In accordance with Criterion 2.3 “Radiation Exposure in the Environment” of the Safety Criteria for Nuclear Power Plants, those plant components required to achieve the protection goals specified therein must be protected against external events such that they can fulfill their tasks during specified normal operation and in case of design basis accidents.

(3) The non-watertight building structures are usually protected against the penetration of water by using a structural waterproofing in accordance with standards series DIN 18195.

(4) As an alternative to the “black tank” type of structural seal (i.e., by a bituminous coating) other structural types may be used like, e.g. the “white tank” (i.e., a protective function given by waterproof concrete structures). These alternatives are not dealt with in this safety standard. However, it shall be verified that these alternatives are designed and manufactured in accordance with the requirements as specified in applicable standards regarding protection against ingress of water (e.g. WU-Guideline) as well as with the additionally applicable requirements for nuclear power plants.

(5) The design of the structural waterproofing of nuclear power plants is, additionally, required to take the following into account:

a) loading conditions due to ionizing radiation (from specified normal operation and plant-internal design basis accidents),
b) dynamic loading conditions (from earthquakes and plant-internal design basis accidents),
c) loading conditions due to a pressure increase (from floods and plant-internal design basis accidents),
d) thermal and chemical loading conditions (from plant-internal design basis accidents).

(6) In accordance with the Incident Guidelines, the load cases ‘Aircraft crash’ and ‘Pressure waves from chemical reactions’ are not considered as being design basis accidents. This safety standard does not specify any requirements for these load cases.

(7) In accordance with Sec. 9 para. 1 No. 9 Radiological Protection Ordinance, together with the Water Resources Act and with provisions of the Länder (Federal States) regarding storage of substances detrimental to water quality, measures must be taken to protect ambient water and soil.

(8) During specified normal operation, no credit is taken from the presence of structural waterproofing with regard to holding back radioactively contaminated fluids. Drip and drain wells, floor thresholds as well as surface coatings of walls and floors are provided with respect to this task as specified in safety standards KTA 3603 and KTA 3604. However, in the case of plant-internal design basis accidents which might also result from external events, e.g., rupture of a pressurized component, the above-mentioned measures might not anymore be fully effective due to the direct thermal and mechanical influences. In such a case, a functional structural waterproofing will still ensure that no radioactively contaminated fluids would leak to the environment (into the soil, into the ground water).

1 Scope

(1) This safety standard applies to the structural waterproofing that can be used for the protection of safety-related plant components against the penetration of water in the case of loading conditions from

a) ionizing radiation during specified normal operation,
b) earthquakes in accordance with KTA 2201.1,
c) floods in accordance with KTA 2207, and
d) plant-internal design basis accidents including ionizing radiation.

(2) This safety standard also applies to that structural waterproofing under para. 1 that supplements the measures taken in accordance with KTA 3603, KTA 3604 and KTA 2207 to protect the ambient water and soil against the leakage of radioactive fluids released due to the loading conditions from earthquakes or plant internal design basis accidents.

2 Definitions

N o t e :
The other terms used in this safety standard with regard to structural waterproofing are in accordance with those of DIN 18195-1.

(1) Specified normal operation

The specified normal operation encompasses

a) operating processes for which the plant, assuming the able function of all systems (fault free condition), is intended and suited (normal operation);
b) operating processes which occur in the event of a plant component or system malfunction (fault condition) as far as safety related reasons do not oppose continued operation (abnormal operation); and
c) maintenance procedures (inspection, servicing, repair).

(2) Design basis accident

A design basis accident is a sequence of events the occurrence of which prevents the continued operation of the installation or the work for safety-related reasons, and for which the installation is designed or for which precautions have been taken to protect the work concerned.

(3) Stress-free zone

A stress-free zone is considered to be that part of the floor area of the foundation slab which, in case of a short-term eccentricity of vertical loading, mathematically would not lead to any compressive loading on the structural waterproofing.

(4) Flow path

The flow path is the shortest distance from the center of a pressure area to that one place on the rim where the bitumen could be extruded.

N o t e :
To determine the flow path – even in the case of an uneven foundation slab load distribution – the foundation areas can be subdivided into regular shaped partial areas with an approximately constant pressure loading.

3 General Requirements

(1) The design and construction of the structural waterproofing and that of the related grooves shall take the requirements in accordance with DIN 18195 Parts 1 through 6 and Parts 8 through 10 into account and, in addition, meet the requirements specified under Section 4 through 6.

(2) The top edge of the structural waterproofing shall be arranged in accordance with DIN 18195-1 and DIN 18195-6.

(3) With regard to flood protection, the structural waterproofing shall reach up to the height of the water level of the design-basis flood in accordance with KTA 2207 or the structural area above the top edge of the structural waterproofing as under para. 2 shall be designed such that the leak tightness of the building structure is ensured to the extent of the scope of protection in accordance with KTA 2207.

4 Protection Against the Penetration of Water

4.1 Dynamic Loading Conditions

4.1.1 Surface Loading Perpendicular to the Structural Waterproofing Plane

(1) No limitation is required regarding the dynamic surface loading perpendicular to the plane of the structural waterproofing even if the limit values for compressive loading in accordance with standards series DIN 18195 and with **Table 4-1** of this safety standard are exceeded.

(2) In case of structural waterproofing in the area of a stress-free zone which, in particular, can occur in light, shallow-based and slender buildings, the following requirements shall be taken into consideration:

a) It is recommended that any gap aperture in the plane of the foundation slab waterproofing be avoided.

b) If a gap aperture in the structural waterproofing plane cannot be avoided, then the functional capability of the structural waterproofing shall be demonstrated and, if necessary, constructive or waterproofing measures shall be taken (e.g., provision of a predetermined breaking surface parallel to the waterproofing plane between base concrete and structural waterproofing).

4.1.2 Surface Loading Parallel to the Structural Waterproofing Plane

(1) If, due to dynamic surface loadings, the shear stresses in a bitumen-glued structural waterproofing parallel to the its plane lie within Region I of **Figure 4-1** then no additional design measures are required with regard to the absorption of thrust forces.

(2) If the determined shear stresses lie within Region II of **Figure 4-1** then, to enhance the overall support stability of the structure, appropriate design measures with regard to the absorption of the entire thrust force shall be provided such as, e.g., cams or trunnions. In this case, the thrust force deformation occurring in the foundation slab waterproofing surface of the foundation slab due to a compression of the waterproofing in the trunnion support surface may be neglected.

4.1.3 Structural Waterproofing Above Movement Joints

(1) In case structural waterproofing is required above movement joints then, in addition to the long term relative movements in accordance with standards series DIN 18195, the movements of short-duration (size and direction) due to a dynamic loading from earthquakes and plant-internal design basis accidents shall also be taken into consideration. With regard to dynamic loading, the movement joints shall be designed as a loose and fixed flange construction of Type II in accordance with Sec. 7.4.2 DIN 18195-8. Elastomeric groove strips (loop-shaped) shall be used for the waterproofing.

(2) The groove strips shall be chosen to comply with the maximum expected relative movement between the groove edges and with the maximum expected external water pressure as specified under Section 4.2.

Note:

The maximum expected movements result from the relative movements between structural parts at the respective location (change of groove width, groove offset, thrust force deformation).

(3) In the case that two independently oscillating structural parts affect one groove construction, then the design of the groove construction may be based on a superimposition of the individual displacements in each direction by the square root method.

(4) The design of loop-shaped groove tapes shall be based on the following calculations:

$$L_m \geq L^* \qquad (4\text{-}1)$$

where

L_m: average loop length of the preselected groove tape

L^*: necessary loop length (mathematical distance between the loop end points multiplied by a water-pressure dependent coefficient)

$$L_m = \frac{R_a + R_i}{2} \cdot \pi \qquad (4\text{-}2)$$

where

R_a: outside radius of the loop

R_i: inside radius of the loop

$$L^* = f \cdot \sqrt{(R_a + R_i + d)^2 + V^2 + S^2} \qquad (4\text{-}3)$$

d: deformation in the x direction (change of the groove width)

V: deformation in the y direction (groove offset)

S: deformation in the z direction (thrust force deformation)

f: water pressure coefficient

f = 1.10 at p = 2.0 bar
f = 1.05 at p = 1.0 bar
f = 1.02 at p = 0.5 bar
f = 1.00 at p = 0.0 bar

p: external water pressure

The directions of loading in a half-round-loop groove tape are shown in **Figure 4-2**.

4.1.4 Penetrations

Penetrations shall be designed as movable constructions and shall be attached by loose and fixed flange constructions to the other structural waterproofing.

Note:

Attention shall be paid to the requirement that the loading pressure between the sealing material and the fixed flange of movement joints and penetrations must be maintained over a long period.

4.1.5 Protective Coating

Design measures shall be taken to prevent a relative movement between the structural waterproofing and any protective coating as far as possible. Any relative movements between the structural waterproofing and the structural component shall be precluded.

4.1.6 Support Structure for Structural Waterproofing

(1) It shall be ensured that any cracks in the support structures for the structural waterproofing (those structural components which absorb the external water pressure) caused by dynamic load conditions from design basis accidents are limited to a maximum crack width of 4.0 mm; this is a requirement that deviates from DIN 18195-6.

(2) This requirement is met without further certification, provided, in the region of the structural waterproofing the maximum distance between the reinforcement rods of the structural concrete stays in accordance with Sec. 11.2.3 and Table 21 DIN 1045-1.

(3) The requirement of para. 1 is also met, provided, in the region of the structural waterproofing the average crack width on the external surfaces of the structural concrete is limited to 30 per cent of the crack width limit, i.e. to a maximum value of 1.2 mm.

Note:

Together with the design being in accordance with DIN 1045 and DIN 25449 as well as with KTA 2201.3 "Design of nuclear power plants against seismic events; Part 3: Design of structural components" (in preparation), this also ensures that the requirements of Sec. 5.4 DIN 18195-6 are met with regard to crack misalignment and crack width at the time of their formation.

(4) The base concrete shall be structurally reinforced to ensure a uniform crack distribution.

4.1.7 Design of Structural Waterproofing

The structure types of the structural waterproofing shown in **Table 4-1** meet the requirements regarding functionality with regard to the predetermined breaking surface specified under Section 4.1.1 para. 2, to the shear stresses shown in **Figure 4-1** and to the crack bridging specified under Section 4.1.6 paras. 1. In the case of other structure types and of other waterproofing materials than those listed in **Table 4-1**, their suitability shall be certified.

4.2 Internal Pressure Increase

If a pressure increase must be assumed to occur on the interior side of the structural waterproofing due to earthquakes or plant internal design basis accidents, it shall then be certified that the function of the structural waterproofing is not endangered. This certification may be based on an average value of the ground-water level.

4.3 Thermal and Chemical Loading Conditions

(1) The structural waterproofing shall, in particular so at the grooves, shall be protected against plant internal fires and against the influence of hot or aggressive media such that it can fulfill its safety related task.

Note:

Fire protection measures are specified in safety standards KTA 2101.1, KTA 2101.2 and KTA 2101.3.

(2) Precautionary measures shall be taken to prevent combustible fluids from seeping into the structural grooves.

(3) If it is possible that chemically aggressive media could reach the interior side of the structural waterproofing then the chemical resistance of the structural waterproofing shall be certified.

4.4 Loading Condition from Ionizing Radiation

(1) The resistance of the waterproofing materials against the ionizing radiation to be expected at the installation location during specified normal operation and in case of plant internal design basis accidents shall, basically, be certified in particular regard to the groove regions.

(2) However, the certification specified under para. 1 is required only if – either during specified normal operation or in case of one of the design basis accidents in accordance with Sec. 49 StrlSchV – the absorbed dose at the installation location in the case of bituminous materials exceeds 10^4 Gy or in the case of plastic materials 10^2 Gy.

5 Protection Against the Release of Radioactive Liquids

If the structural waterproofing is involved in the protection of the ambient water and soil from the release of liquids – due to one of the design basis accidents in accordance with Sec. 49 para. 1 StrlSchV – then the function of the structural waterproofing shall also be ensured for this case. This requires taking into consideration

a) the pressure loading conditions as specified under Section 4.2,

b) the thermal and chemical loading condition as specified under Section 4.3, and

c) the loading conditions from ionizing radiation as specified under Section 4.4.

Note:

Regarding the release of radioactive liquids in the case of design basis accidents, it is common practice to take credit of the retention function of the structural waterproofing.

6 Tests and Inspections

6.1 Reviews in the Course of Planning

The following points shall be reviewed:

a) whether the safety related requirements for the structural waterproofing are taken into account with respect to the load cases and load case combinations to be considered,

b) the loading conditions that the structural waterproofing must resist during specified normal operation and in case of design basis accidents as well as during construction, and

c) the documents pertaining to the planned structural waterproofing, e.g.,

   ca) plan of the general arrangement of the structural waterproofing (overview plan),

   cb) structure of the waterproofing elements,

   cc) creation and location of fillets and grooves, edges and corners,

   cd) arrangement and design of the groove seals,

   ce) design of the assembly parts and of the penetrations,

   cf) contact joints of the structural waterproofing, and

   cg) design of the protective coatings.

6.2 Construction-accompanying Testing and Supervision

(1) The surveillance in accordance with DIN 18200 of the waterproofing materials shall be certified; this surveillance consists of an internal audit and of an external audit.

(2) Within the framework of the quality assurance measures specified for the construction site in accordance with Sec. 6 KTA 1401, a receiving inspection shall be performed to check whether or not the materials delivered to the construction site are in conformance with the required quality characteristics.

(3) The receiving inspection, the supervision of the construction, the acceptance test and the documentation shall be performed in accordance with the general requirements specified in safety standard KTA 1401.

Note:

With regard to documentation, cf. KTA 1404 "Documentation during the construction and operation of nuclear power plants".

Structure Type	**Pressure Loading Condition, $p_{stat.}$ and Flow Path, R**	**Layer Sequence** independent of the penetration depth	
		Foundation Slab (from top to bottom)	**Wall** (from inside to outside)
1	≤ 0,6 MN/m² and ≥ 10.0 m	(Protective Concrete)	(Structural Concrete) [1) 2)]
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Plastic damp proof sheets BA PVC-P-BV-2,0 DIN V 20000-202, Type T, in accordance with DIN EN 13967	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Bitumen sheeting for waterproofing of roofs G 200 DD, in accordance with DIN 52130	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Plasticized-PVC sheet, bitumen compatible, 2 mm, in accordance with DIN 16937	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		(Subconcrete) [1)]	(Protective Coating)
2	≤ 1.5 MN/m² and ≥ 2.0 m	(Protective Concrete)	(Structural Concrete) [1) 2)]
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Plastic damp proof sheets BA PVC-P-BV-2,0 DIN V 20000-202, Type T, in accordance with DIN EN 13967	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Calotte-checkered copper band CU-DHP 0.1, in accordance with DIN EN 1976	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Plastic damp proof sheets BA PVC-P-BV-2,0 DIN V 20000-202, Type T, in accordance with DIN EN 13967	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		(Subconcrete) [1)]	(Protective Coating)
3	≤ 2.0 MN/m² and ≥ 1.0 m	(Protective Concrete)	(Structural Concrete) [1) 2)]
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Plastic damp proof sheets BA PVC-P-BV-2,0 DIN V 20000-202, Type T, in accordance with DIN EN 13967	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Calotte-checkered copper band CU-DHP 0.1, in accordance with DIN EN 1976	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Bitumen sheeting for waterproofing of roofs G 200 DD, in accordance with DIN 52130	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Calotte-checkered copper band CU-DHP 0.1, in accordance with DIN EN 1976	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		Plastic damp proof sheets BA PVC-P-BV-2,0 DIN V 20000-202, Type T, in accordance with DIN EN 13967	
		Adhesive layer of unfilled B 85/25, 1.5 kg/m² ± 0.5 kg/m²	
		(Subconcrete) [1)]	(Protective Coating)

1) The subconcrete of the foundation slab and the structural concrete of the wall shall be prepared such that an average adhesive tensile strength ßHZ ≥ 1.5 N/mm² (single values ≥ 1.0 N/mm²) is achieved. The certification shall be performed in accordance with Appendix 2 ZTV-SIB 90.

2) In case the wall region of the structural concrete must be poured against the waterproofing, then special measures to enhance the adherence shall be provided for the border surface between the structural concrete and the waterproofing (e.g., in accordance with Sec. 5.12 and 5.13 ARBIT-Brochure No. 61 “Waterproofing with Bitumen”).

N o t e :

In the case of other types of waterproofing structures and the use of other waterproofing materials, cf. Section 4.1.7.

Table 4-1: Different types of waterproofing structures

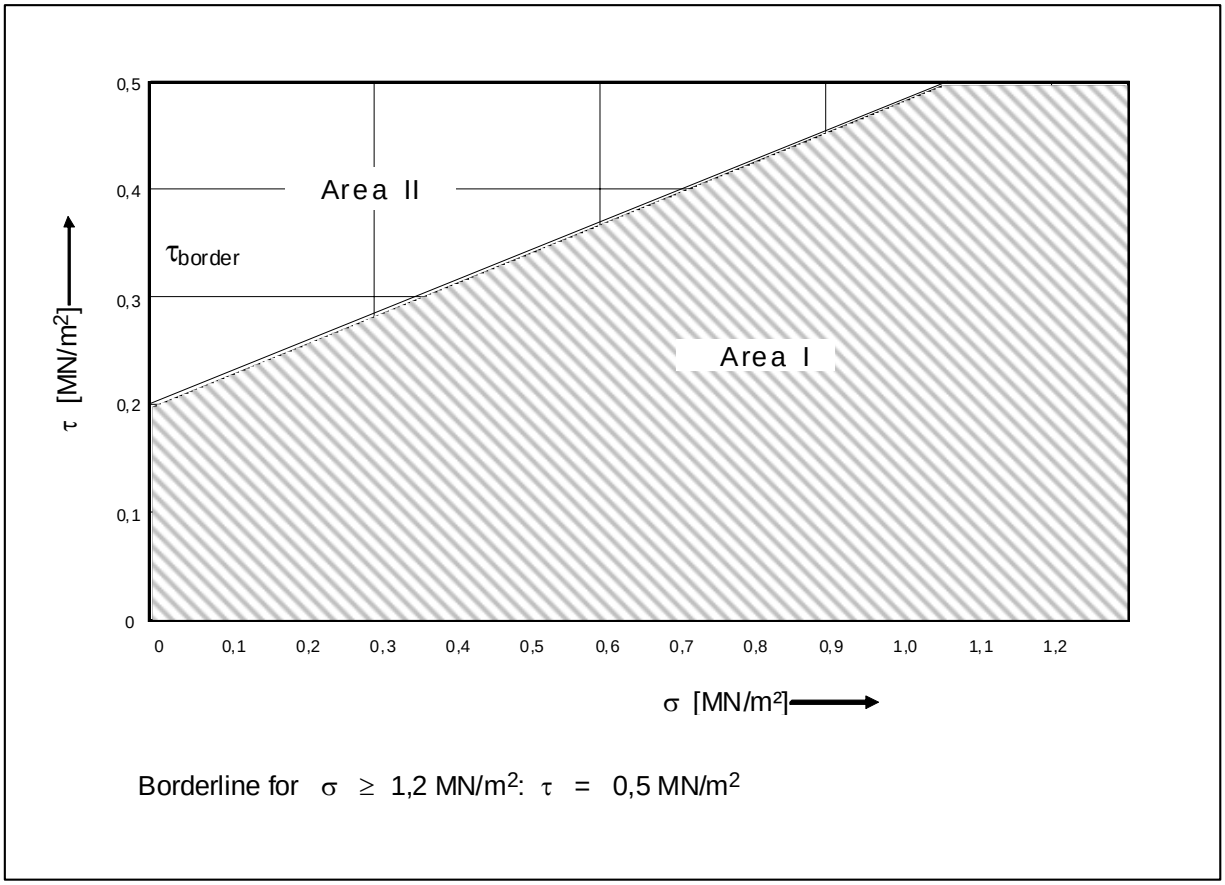

Figure 4-1: Shear stress, τ, as specified under Section 4.1.2 and the corresponding mean normal stress, σ, in case of a dynamic surface loading condition

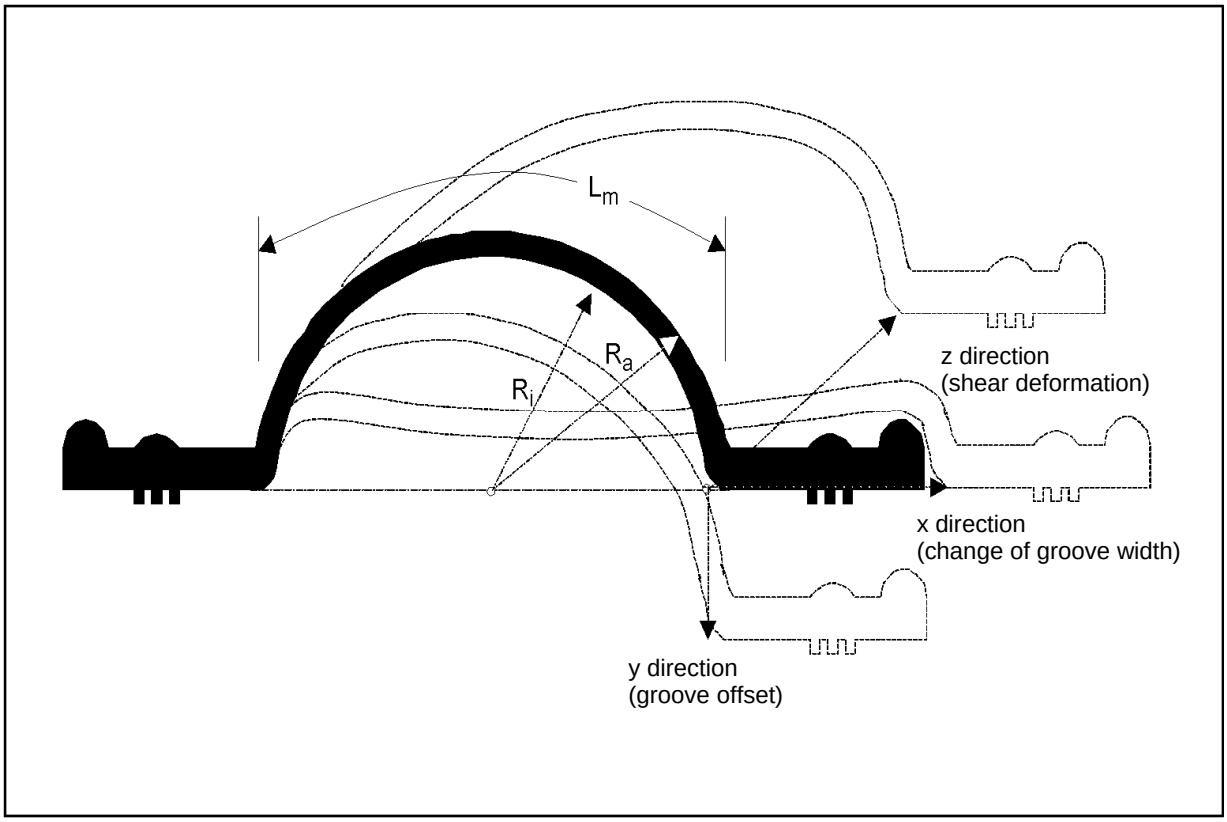

Figure 4-2: Directions of loading forces in a half-round-loop groove band (example)

Appendix A

Regulations Referred to in this Safety Standard

(Regulations referred to in this safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.)

AtG		Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act – AtG) of December 23, 1959, revised version of July 15, 1985 (BGBl. I, p. 1565), most recently changed by Article 1 of the Act of December 8, 2010 (BGBl. I, p. 1817)
StrlSchV		Ordinance on the protection from damage by ionizing radiation (Radiological Protection Ordinance – StrlSchV) of July 20, 2001 (BGBl. I 2001, No. 38, p. 1714), most recently changed by Article 2 of the Act of August 29, 2008 (BGBl. I 2008 No. 40, p. 1793)
Safety Criteria	(1977-10)	Safety criteria for nuclear power plants of October 21, 1977 (Banz 1977, No. 206)
Design Basis Accident Guidelines	(1983-10)	Guidelines for the assessment of the design of nuclear power plants with pressurized water reactors against design basis accidents as defined in Sec. 28, para. 3 StrlSchV (Design Basis Accident Guidelines) of October 18, 1983 (Banz 1983, No. 245a)
KTA 1401	(1996-06)	General Requirements Regarding Quality Assurance
KTA 2201.1	(1990-06)	Design of nuclear power plants against seismic events; Part 1: Principles
KTA 2207	(2004-11)	Flood protection for nuclear power plants
KTA 3603	(1991-06)	Facilities for treating radioactively contaminated water in nuclear power plants
KTA 3604	(2005-11)	Storing, handling and on-site transportation of radioactive substances (other than fuel elements) in nuclear power plants
DIN 1045-1	(2008-08)	Concrete, reinforced and prestressed concrete structures – Part 1: Design and construction
DIN EN 1976	(1998-05)	Copper and copper alloys – Cast unwrought copper products; German version EN 1976:1998
DIN EN 13967	(2007-03)	Fexible sheets for waterproofing – Plastic and rubber damp proof sheets including plastic and rubber basement tanking sheet – Definitions and characteristics; German version EN 13967:2004 + A1:2006
DIN 18195-1	(2000-08)	Water-proofing of buildings – Part 1: Principles, definitions, attribution of waterproofing types
DIN 18195-2	(2009-04)	Water-proofing of buildings – Part 2: Materials
DIN 18195-3	(2000-08)	Water-proofing of buildings – Part 3: Requirements to the ground and working properties of materials
DIN 18195-4	(2000-08)	Water-proofing of buildings – Part 4: Water-proofing against ground moisture (capillary water, retained water) and non-accumulating seepage water under floor slabs and on walls, design and execution
DIN 18195-5		Water-proofing of buildings – Part 5: Water-proofing against non-pressing water on floors and in wet areas; design and execution
DIN 18195-6	(2000-08)	Water-proofing of buildings – Part 6: Water-proofing against outside pressing water and accumulating seepage water; design and execution
DIN 18195-8	(2004-03)	Waterproofing of buildings and structures; waterproofing over movement joints
DIN 18195-9	(2010-05)	Waterproofing of buildings and structures; penetrations, transitions, closures
DIN 18195-10	(2004-03)	Waterproofing of buildings and structures; protective layers and protective measures
DIN 18200	(1995-11)	Assessment of conformity for construction products – Certification of construction products by certification body
DIN 25449	(2008-02)	Reinforced and prestressed concrete components in nuclear facilities - Safety concept, actions, design and construction
DIN 52130	(1995-11)	Bitumen sheeting for water-proofing of roofs - Concepts, designation, requirements
WU-Guideline	(2003-11)	DAfStb-Guideline; Waterproof concrete structures
ZTV-SIB 90	(1990)	Additional technical contractual conditions and guidelines for the protection and repair of structural concrete parts
ARBIT-Brochure No. 61	(2000-08)	Waterproofing with bitumen (ARBIT – Working Committee of the Bitumen Industry)