

### Damage patterns of brick masonry

Damage pattern	Damage process	Possible cause(s): Exact damage and cause analysis required especially the source of the moisture	Restoration proposal: Which measure and method are lasting and suitable for the application in a historic/protected building?
Loss of material in parts, at the surface or of whole stones	Loss of adhesion: Loss of small, compact particles up to complete loss	Moisture and salt deposit in pores	Stop moisture and salt input according to their source e.g. through horizontal masonry barrier or rain protection at the masonry crown, replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model
	Spalling: Scale off of compact particles	Moisture and salt deposit in pores	Replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model
	Layers peel off: Thin, flat particles peel off parallel to the ground surface	Moisture and salt deposit in pores	Stop moisture and salt input according to their source e.g. through repointing of damaged joints above the respective area, Repair damaged stones with stone substitute mortar, Check the permeability of the mortar joints and if needed repoint them according to the historic role model

	Layers peel off: Thin layers less than 1 mm parallel to the ground surface	Moisture and salt deposit in pores	Replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model
	Layers peel off: Thick layers of some millimeters up to centimeters parallel to the ground surface	Moisture and salt deposit in pores	Stop moisture and salt input according to their source e.g. through horizontal masonry barrier, replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model
	Separation of major, compact pieces	Loss of adhesion of the bond due to salt deposit or frost	Stop moisture and salt input according to their source e.g. through rain protection at the masonry crown, replace damaged stones, Check the permeability of the mortar joints and repoint them according to the historic role model
	Bonding failure between brick and mortar	Loss of adhesion of the bond due to salt deposit or frost	Check the permeability of the mortar joints and repoint them according to the historic role model
White coating at the surface	Material attachment: Blooming (crystal salts on or in the stone and/or mortar)	Moisture transport in the brickwork: Moisture dissolves salt in the mortar or concrete and transports it via capillary active bricks to the wall surface. Here the salt settles down after evaporation of the moisture as a white veil.	Clean dry, Stop moisture and salt input according to their source e.g. through rain protection at the masonry crown and roof edge

Discoloured stones, sometimes with little cracks and deposits	Surface weathering with discolouration, fading, deposits, patina crustification	Weather impacts (rain- and snowfall), moisture, change between frost and thawing, radiation, temperature, wind), environmental impacts (air pollution, sour rain)	No action needed as long as masonry bond and joint net are free of damages
Greening on stones and broken or porous mortar joints	Biological greening through moss, algae, lichenic, plants (grass, bushes, trees, one season plants, perennial herbs)	Open joints and broken stones, long wet periods	Stop moisture and salt input according to their source e.g. through restoration of damaged downpipes and cornice coverings, if possible cut down the neighbouring bushes, replace damaged stones, check the mortar joints and repoint them according to the historic role model
Cracks in stones or in the joint net	Shrinking and expansion because of temperature changes	Connection to neighbouring building components made of different materials or rat exposed positions	Control completely the masonry bond and if applicable restore the connection to the backing masonry in case of facing masonry trough supplementary installation of wire ties. Seal cracks in a perma-elastic manner against moisture (not tensional), Restore remaining joint net according to the historic role model

Decomposition of materials (stone or joints)	Decomposition of materials (stone or joints)	Different settlement of the building	First implement static investigation, control the complet masonry bond and if applicable restore the connection to the backing masonry in case of facing masonry trough supplementary installation of wire ties Grout cracks tensional with epoxide resin. Restore joint net according to the historic role model
Capillary cracks in the stone	Single cracks in the stone, less than 0.15mm	Cracks in glazing because of moisture in the stone or frost expansion	No action needed as long as masonry bond and joint net are free of damages
Net-like cracks with typical net pattern on the stone surface	Net-like cracks in the stone, less than 0.15mm	Thermal stress or frost	No action needed as long as masonry bond and joint net are free of damages
Radial cracks on the stone surface	Radial cracks, more than 0.15mm	Partial material expansion in or beneath the stone surface	No action needed as long as masonry bond and joint net are free of damages
Net-like cracks with typical net pattern on the stone surface	Net-like cracks in the stone, less than 0.15mm	Thermal stress or frost	No action needed as long as masonry bond and joint net are free of damages
Voides in the joint net	Decomposition of mortar chunks, destabilising of the brickwork bond	Washed out bonding agent in the mortar or loss of adhesive capacity to the stone, infiltration of plants and moisture possible that will lead to frost damages; maybe the joints surfaces were not properly smoothed so water is able to infiltrate	Restore joint net according to the historic role model, stop moisture and salt input according to their source through e.g. through rain protection at the masonry crown

Mortar cracks and disconnection of stones	Diverse cracks because of insufficient bond of mortar and stones	Wrong composition on joint mortar, high strength and low elasticity or excess of the adhesive tensile strength to the stones, too strong compression while jointing the mortar and too quick dry out, movement in the brickwork	Check the mortar joints and if needed repoint them according to the historic role model, if applicable restore the connection to the backing masonry in case of facing masonry trough supplementary installation of wire ties
Cracks in the brick facade of a cavity wall	Cracks mostly in the flank area	Missing wire ties or few wire ties in an insufficient number for a cavity wall >Adverse effect for the stability of the facing masonry	Control completely the masonry bond and if applicable restore the connection to the backing masonry in case of facing masonry trough supplementary installation of wire ties, restore joint net according to the historic role model
Cracks in the facing masonry	Corrosion of the wire ties	Zincd wire ties were used until the amendment of the masonry regulation (DIN 1053-1 Mauerwerk) in 1974. Those wire ties corrode after installation. >Adverse effect for the stabiity of the facing masonry, >Disconnection of pieces of the facing masonry, Investigation of the wire ties through endoscopy into the cavity space of the wall	Control completely the masonry bond and if applicable restore the connection to the backing masonry in case of facing masonry trough supplementary installation of wire ties, restore joint net according to the historic role model

<p>Chip off at stones (view also <i>Loss of material</i>)</p>	<p>Bursting effect because of frozen water in the stones</p>	<p>The contained water in the stones gets frozen and expands its volume. As soon as the pores are filled up and the strength of the stones cannot bear the pressure any longer cracks occur or layers of the stones peel off.</p> <p>A high absorbency of the stone, low shear strength, little pore volume and adverse pores arrangement support the material destruction while frost.</p>	<p>Stop moisture and salt input according to their source e.g. through horizontal masonry barrier or rain protection at the masonry crown, replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model</p>
<p>Chip off at stones (view also <i>Loss of material</i>)</p>	<p>Bursting effect because of frozen water in the stones</p>	<p>Mortar joints with high water permeability support high water content in the masonry bond and thus the bursting while frost.</p> <p>What makes it worse is the fact that bricks with tight skin are taking water via the mortar joints and the stone sides (&gt;balance moisture) but emit the water through the tight facing surface rather reluctantly. The risk of the bursting effect increases.</p>	<p>Stop moisture and salt input according to their source e.g. through horizontal masonry barrier or rain protection at the masonry crown, replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model</p>
<p>Pieces of joint mortar fall down</p>	<p>Bursting effect because of frozen water in the masonry mortar</p>	<p>Mortar gets brittle through water infiltration and frost.</p> <p>&gt;Bond of stones and mortar is disrupted; movements in the masonry bond are increasingly possible.</p>	<p>Stop moisture and salt input according to their source e.g. through horizontal masonry barrier or rain protection at the masonry crown, replace damaged stones, Check the permeability of the mortar joints and if needed repoint them according to the historic role model</p>

Moisture in brickwork (as first damage image)	Soaking of the brickwork	Rain water ponds because of dirt/leaves/dead animals in gutters and downpipes so constant water infiltration into the brickwork is possible.	Stop moisture and salt input according to their source e.g. through restoration of damaged downpipes and rain gutters, replace damaged stones, check the mortar joints and repoint them according to the historic role model
Adhesion loss between stones and joints; joint image sustainably changed	Dust film on stone sides prevent further adhesion	Skin of the stones are opened/ cut off because of wrong usage of devices while removing the joints	Remove the mortar joint again but this time manually through scrapping out, blow out the dust by compressed air, repoint the mortar joints according to the historic role model
Porous stone surface	Sandblasting or other cleaning methods damage the stone skin	The stone surface was opened through sandblasting	Hydrophobic treatment to minimise the moisture input of driving rain
Loss of material or salt deposit at the stone surface (see above)	Increased moisture and salt transport into the stone	Substitute mortar was chosen too strong for the joint net refurbishment compared to the stones.  Lowered permeability of the mortar leads to increased moisture and salt deposit in the stones.	Scrap out the mortar joints manually, repoint the joints according to the historic role model