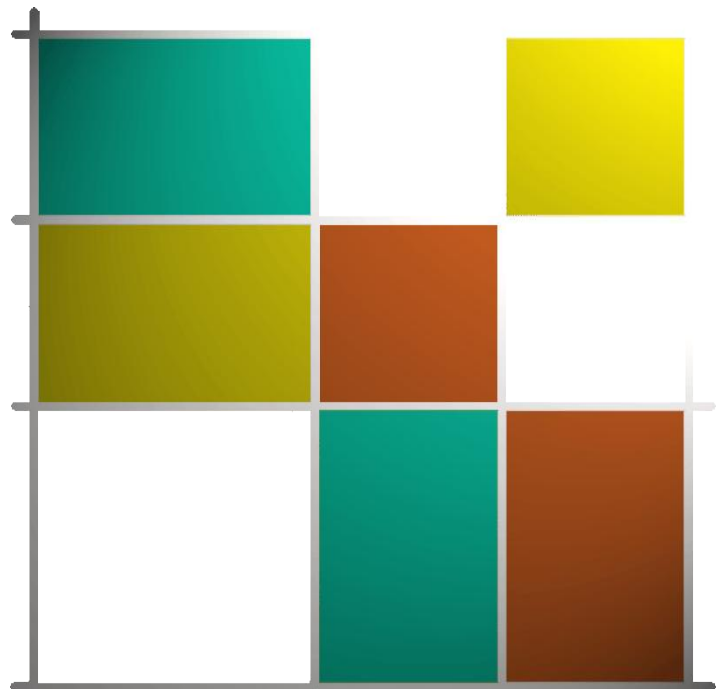


SJ MEPLA

Brief Introduction

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1 Geometry

- The panel form can be freely defined without delimitation. The corner points are to be entered in mathematically positive order (against the clockwise direction).
- The edges of the panel can be defined by the indication of a rotation center as well in form of arcs. For a complete description of a round edge the direction of rotation is needed. Thus it must be specified whether the circular arc turns positive (against the clockwise direction) or negative around the rotation center.
- The element mesh will be generated automatically by a “free”-meshing algorithm so that any geometry can be build. The edges thereby are not allowed to over-cross.
- As additional input the size (side length) of the elements which shall be produced is needed.
- The accuracy of a finite element calculation depends on the mesh quality and quantity. The side length of the elements is preset to 120 mm, which is usually sufficient for normal panes sizes.

2 Layer

2.1 Order of layers

- Currently the German standards do not allow to set the bonding effect of the PVB interlayers into account (except for insulating glass units). Therefore laminated glass panes must here be calculated in one of the two following methods:
 - o Usage of a very small modulus of elasticity for the bonding material e.g. $E = 0.01 \text{ N/mm}^2$. Then the glass panels are slightly connected and can more or even slide of each other.
 - o Or the loads are partitioned according the specific stiffness of the regarded pane. For example.: A laminated glass pane 10/0.76/10 mm is loaded by a face load of 0.75 kN/m^2 . Then one pane can be calculated with a thickness of 10 mm, which will receive a half of the loading (0.375 kN/m^2).
- For countries where the bonding effect can be considered, it's possible to calculate laminated glass panels of any layout.
- The total number of layers must be odd, as two glass panels always must encapsulate the intermediate bonding layer.
- The numbering of the panes takes place from the bottom to the top (in positive z-direction), so as if they are laid on.

2.2 Insulated glass units

- Is more than one glass package selected (short denoted as: package), the system will be considered as insulted glass unit.

- Then the items for the description of the intermediate gap will open. Here must be defined
 - o the filling gas (air, argon,...),
 - o the distance of the panes
 - o and the temperature changes for the gas.
- For calculations of insulating glass units the external (outside) pressure must be given. As all calculations are done in the units „N/mm²“also the outside pressure must be defined in this unit.
 - o Conversion : 1 bar = 0.1 N/mm², so that a usual air pressure of 1.010 bar must be keyed in with 0.101 N/mm².
- In addition a difference of height between the production and installation of the insulating glass unit may be specified by ΔH [m].
- Further information will be found under climate loads.

3 Supports

3.1 Springs

- Spring supports as unique acting springs, which may be set at any desired position in the plate for each of the 3 directions x, y and z and the 2 rotations rigidities C_{φ} and C_{θ} .
- The unit for the spring rigidities is N/mm and Nmm/rad.
- When a stiffness of 0 N/mm is set, no spring stiffness will act in this direction.
- Automatically there are 3 springs suggested. In the first corner point of the system in x- and y direction and in the second point only in y- direction. These very weak springs (default value of 1.0 N/mm) are not designed to carry any loads, only to prevent the system for uncontrolled in-plane moving and rotating.

3.2 Edge supports

- From the table of support conditions the appropriate bearing design can be chosen. These bearings will also be set for the thereover lying edges of the next packages - if some has been defined.
- The standard simple support for glass pane edges is type 0.
- For improvement of symmetry conditions sometimes type 2 or/and 3 will be used. Using this kind of supports the system can maximally be halved or quartered to save computation time. Then also the loads must comply to this symmetry condition and must be reduced in same way.

3.3 Glass point fixings

- Ten different kinds of glass fixings are available:
 - o type 1: Countersunk fixing
 - o type 2: Disk fixing
 - o type 3: Circular edge clamp support
 - o type 4: Angular edge clamp support
 - o type 5: Circular downholder
 - o type 6: Angular downholder

- type 7: Adhesive plate fixing (without borehole)
 - type 8: Countersunk fixing within the first pane only
 - type 9: Countersunk fixing within the first package of an DGU
 - type 10: Disk fixing within the first package of DGU
-
- The glass fixings may be set at any desired position in the glass plate. But, an angular clamp support cannot be set however into a corner position. If clamp supports are set into the proximity of a corner, then here only straight borders are possible and no round edges.
 - The border of the glass fixings type 1, 2, 7, 8, 9 and 10 may not lie nearer than approx. 25 mm to the edges of the plate.
 - The glass holders of kind 3 to 6 (clamp supports) have a supporting effect over the separating rubber pad.
 - The clamp fixings of kind 5 and 6 can't be used to support the pane in plane direction. They only work as downholders. Tangential to the glass edge all kind of clamp supports cannot transfer forces to the glass. A binding of these clamping fixings using rods must be regarded very conscientiously in order not to produce a kinematic system.
 - A glass point fixing must be defined first over its reference. Thus also different kinds in a plate can be used.
 - The pre-definitions are fictitious standard fixings with frequently occurring dimensions, preset of us.
 - New custom fixings can be permanently stored in the data base under "settings/glass point fixings", so that they can always be reused.
 - The finite element mesh is produced automatically. It can occur however that an error message appears. Then the mesh could not be generated correctly and the element size must be changed slightly up and down (+10 / -10mm).
 - It is to note on an evenly distributed finite element mesh around the point fixing, in order to obtain optimum results.
 - The spring rigidities describe the rigidity of the sub-construction at the place of the fixings base point or also its design. When the rotational degrees of freedom C_φ and C_θ are set to zero, a ball shaped head will be described, which can freely rotate.
 - Alternatively the glass fixing can be connected using a sterical orientated rod. This rod has hinges at his both ends, where it will be fixed at the wall and the glass fixings base point.
 - The distance Z_h describes the position of the place, where the fixing design ends and the springs are acting. E.g. if this point is lying 15 mm under the bottom face of the plate, then this distance must be indicated with -15mm (negatively), as its position is located against the direction of the positive z-axis.
 - The rotation behaviour of the clamp fixings (type 3 to 6) (all others always can freely rotate around the z-axis) can be set to "rigid" (standard) or "free". For rigid settings also torsion loads can be transferred by the glass fixing around the z-axis.
 - Clamp supports of type 3 to 6 are automatically set to "free", if a rod has been set as connection.
 - The downholders of type 5 and 6 act only from above (from negative z-direction) the pane (the last glass package). They can be used thereby additionally with other supports to suppress the displacement under suction forces.

- At all point fixings as well forces or moments can be separately applied.

3.4 Spacer

- The usage of spacers allow the definition of unsupported edges for insulated glass units.
- Therefore the edges must be defined, which are not supported and shall receive a spacer to combine the glass edges of these pane packages. This is done in form of the characteristic values for the sealing material (e.g. silicone).
- When a modulus of elasticity of 100 N/mm^2 (and shear modulus 0.0 N/mm^2) with a width of 5 mm is used, thus a almost constant distance is supposed (default).
- Shall a more realistic behaviour be used, a non-linear behaviour can be chosen, so that the distance (gap opening) may elastically increase but decreasing will be suppressed, according to the contact conditions between the panes and the intermediate aluminium profile. This method is only for scientific studies.

3.5 Elastic edge supports (structural glazing)

- The elastic edge supports describe the bearing conditions of a panel which is elastically supported at its borders.
- Contrary to the conditions of the edge supports, which are a rigid (stiff), here the elastic effects of a bearing can be regarded.
- Additionally contact conditions can be chosen, when lifting plate corner may arise.
- If one uses a shear modulus G not equal to zero, then this flexible support works also tangential to the disk plane. This will be the behaviour of bonded edges (structural glazing). The standard value for G is zero!
- The default value for a EPDM strip is: E-modulus = $10 - 40 \text{ N/mm}^2$ with a width and height of the really used elastic profile. (in most cases approx.: $20 \times 5 \text{ mm}$)

3.6 Elastic line supports

- This boundary condition behaves exactly the same as the elastic edge supports, only that it can be located anywhere within the plate. As this supports may not lie at the edges of the panel, it is calculated in another manner, for what here is used a separate register card.
- This elastic line support can as well use contact conditions, so that separation can take place.

3.7 Edge bonding

- For bonded glass edges this kind of bearing can be set.
- All layers of all packages will then be glued with an elastic material.
- When the shear modulus G is set to zero, only normal forces to the glass edge can be transmitted. In tangential direction moving of the pane will then be possible.

- The stresses and reaction forces within the bonding is written into the protocol.

3.8 Edge beam

- At the edges an additional elastic beam can be set. This beam than will bear some loads and will bend in addition to the glass edge.
- For definition the moment of inertia, the cross section area and the density has to be given.
- The kind of bearing at the beginning (A) and ending (B) depends upon the way the edge is supported, where the beam will start and end. Additionally to the taken degrees of freedom further d.o.f. can be set. In this way a beam can be simply supported, when no d.o.f's are set for the enframing borders (e.g. type 0).
- The beginning and ending of the beam is defined in the same direction as the orientation of the corner points (counter clockwise).
- It's not possible to use beams at curved borders.

4 Loads

4.1 Face loads

Constant distributed face loads:

- Face loads results from wind or snow, which acts normal onto the entire panel area.
- Positive are loads, which act in positive z-direction. Thus usually wind and snow loads must be given with a negative sign, as they act against the z-direction onto the panel. Suction wind loads at rough edges or in the lee of buildings must against it be positive defined, as they are pulling at the glass panels.
- The loads must be given in the unit N/mm², so that values in kN/m² must be divided by 1000. Or the value is furthermore written in units kN/m² and „e-3“ is added to this value (so this value is multiplied by 10⁻³). Example: 2.0 kN/m² = 0.002 N/mm² or 2.0e-3 N/mm².

Linear distributed face loads:

- A linear increasing face load (may be constant as well) like water pressure or unequal snow loading can be defined by the use of 2 reference points in y-direction. In between these data y_0 and y_1 the loaded area will be set.
- The calculation of the loaded area is underlying a little approximation at the border lines, which usually do not result in an error force greater than 0.5 N. (see theory handbook)

4.2 Dead weight

- The dead weight can act in any desired direction onto the glass panel.

- This direction is defined by a vector with 3 components (V_x , V_y , V_z), which describes the gravity direction (and so the position of the panel in space).
- Examples:

Position of panel	inclination angle	V_x	V_y	V_z
Horizontal	0°	0	0	-1
vertical (dead weight acts in positive x-direction)	not possible	1	0	0
vertical (dead weight acts in negative y – direction)	90°	0	-1	0
Panel is turned around the x-axis by 45°	45°	0	-1	-1

4.3 Concentrated loads

- Concentrated loads may act at any desired position within the plate.
- The definition of loads take place in the unit of forces [N], which are uniformly distributed over the defined loading area ($L_x \cdot L_y$) and therefore again acts as face loads.
- The position is defined by the center co-ordinates of this loading area.
- In this way also line loads can be specified. When e.g. L_y is chosen very small (e.g. 5 mm) but the length L_x reaches over the entire plate.
- Example: A horizontal line load shall be set in the height of 1 m over the x-axis onto the glass panel with a loading of 1,0 kN/m. The length of the plate is 1.5 m and starts in the origin. The total loading due to this line load is: $1,5\text{m} \times 1,0\text{kN/m} = 1,5 \text{ kN}$. In *Newton* the force amounts to -1500 N (negative, as it shall act against the z-direction onto the plate). The centre of the loading lies at $x = 750\text{mm}$ and $y = 1000\text{mm}$. For the load distribution area a value for $L_x = 1500\text{mm}$ (the length of the panel) and for L_y any desired value can be taken, so that the effect is a line style loading (e.g.: $L_y = 10\text{-}50\text{mm}$).
- Shall loads due to walking persons be set, the load distribution area can be set to $200 \times 200\text{mm}$ with a total load of -1000N (= 100kg weight of a person).

4.4 Line loads

- Line loads can be defined anywhere and as often you need.
- The used unit is [N/mm] or without conversion [kN/m].
- The starting and ending point of the line can lay anywhere. Loaded parts outside the panel are not considered. But it's more accurate, when the load is located within the pane.
- Along this line 3 load directions q_x , q_y , and q_z can be defined.
- The loading width along the line is zero. (see the concentrated loads in contrast)

4.5 Border Line loads

- Along each border line loads may be set, which act transversal onto the border or normal inplane direction.
- This can be done for straight or curved borders.

4.6 Climate loads

- There could be set all kind of climate loads:
 - o Internal pressure of the gas in the gap
 - o barometric pressure (outside the insulating unit)
 - o temperature differences for the filling gas
 - o differences of height between the production and the installation of the insulating unit
- According to the German standard two load cases can automatically be considered:

Load case	Production	Installation	Pressure difference [mbar]	Temperature difference [°]	Note
Winter	Summer +27° / 990 mbar	Winter +2° / 1030 mbar	+40	2-27= -25°	Pane arches inside
Summer	Winter +19° / 1030 mbar	Summer 38° / 1010 mbar	-20	38-19 = 19°	Pane arches outside

These load cases are specified in SJ MEPLA as follows:

Load case	Internal pressure p_i [N/mm ²]	Outside pressure p_a [N/mm ²]	Temperature difference ΔT	Difference of height ΔH [m]
Winter	0.099	0.103	-25°	when lower installed than produced → $\Delta H = -300m$
Summer	0.103	0.101	+19	when higher installed than produced → $\Delta H = 600m$

- These loading conditions can automatically be inserted using the pop up menu Winter/Summer.
- Other climatic loads can be defined separately in a database.

4.7 Pendulum impact (twin tire impactor)

- When glass panels are planned with drop securing function, the German standard TRAV (“Technische Regeln für die Verwendung absturzsichernder Verglasungen”) must be observed to avoid expensive tests. Otherwise pendulum impact tests according to the European Standard DIN EN 12600 must be carried out at side. This test is passed, when no large pieces of broken glass fall to ground – with the result that the distorted glass panels must be replaced.

- In many cases systems are designed, which do not match with these specified dimensions.
- In these and other cases SJ MEPLA can be taken to design the glass panels until these calculations in Germany are accepted for statics from all authorities.
- The dynamic calculation of impact takes place by selecting the point of impact and the drop height of the pendulum body.
- These points of impact shall lie 250 mm away from the edges and corners of the plate or the fixings. Three points of impact shall be examined:
 - o In the centre,
 - o at the corner,
 - o and at the edge of the glass plate.
- The panels have then passed, when the maximal principal stresses are not exceeded (only for pendulum test):
 - o Float glass 80 N/mm²
 - o heat strengthened glass 120 N/mm²
 - o heat toughened glass 170 N/mm²
- For the pendulum simulation the option „non linear calculation“ must be chosen, as the results are otherwise not exact.
- Furthermore the state for the glass plates must be free from static loads. That is,
 - o no face loads,
 - o no concentrated loads,
 - o no dead weight,
 - o no temperature differences,
 - o internal pressure = outside pressure for insulating glass units may act beneath the pendulum impact load. Otherwise these loads are considered as well, which will lead to uncontrolled vibrations of the plate, before the pendulum impacts the pane.
- The pendulum impact onto the first (inside) or last glass package (from outside).

4.8 Load case

- Starting with new predefined loads for wind acting onto the outside and inside pane and snow only loading the outside pane, load combinations with respect to other loads can be set here.
- For this, the loads (suction, pressure or nothing) can be chosen, what the is coupled with the selected load case.
- This combination can additionally be defined with safety factors, only multiplying the selected loads.
- Line loads and point loads cannot be chosen new. They are taken from the definition under `<loads>`.
- To consider the climatic loading, 4 presets can be chosen:
 - o Winter condition (the pane are contracting)
 - o Summer condition (the panes will expand)
 - o Predefined load case (definition took place under `<layer>`)
 - o No climatic loadings
- As well other self defined climatic loads can be stored in a database and may be used here.

- Line loads and point loads must be defined within the loading card *<loads>*. But the coefficients to multiply these loads for a loadcase can be set here.
- The load cases are automatically calculated and written into the protocol. Within the graphics surface these calculations can be shown by selecting *<step>*.

4.9 Safety factors

- According to new standards, safety factors can be set here. This will work in the same way as under *<loadcase>*; but without the possibility to choose new loads.
- All face loads previously defined are considered and multiplied by a safety factor:
 - o Dead weight
 - o Face loads (including linear loads, not applying the total pane area)
 - o Line loads
 - o Point loads
 - o Climatic loads
- The definition of the loading situation is carried out under *<layer>* and *<loads>*.
- The cards *<loadcase>* and *<safety factors>* can't be chosen at the same time.

5 Options

5.1 Linear and non-linear calculations

- Optional linear or non-linear geometric calculation can be set (large deformation lateral to the panels plane).
- The approach of large deformations is significant, when the deformations of a simply supported plate are larger than the thickness of the plate. The plate activates the load carrying mechanism of membran forces which will increase the stiffness and decreased stresses will occur – in contrast to linear calculations, which is a linearisation, only valid for small deflections.

5.2 Stress results

- At any desired positions within the plate points can be selected, where results in form of stresses and displacements shall be obtained (printouts in the protocol).
- These points are determined by their position (x and y) and the according package.

5.3 Maximum stresses

- It can be defined which extremal stresses will be written into the protocol.

- You can chose the maximum principal stresses, the minimal principal stresses and the VonMises stress for metallic panels.

6 General notes

6.1 Mesh refinement

- The element size is as default set to 120 mm. The element discretisation is automatically chosen, so that quadrilateral elements are build.
- This standard element size of 120mm is only a suggestion and may be changed according to the desired accuracy. Therefore is advisable to check the mesh quality by using the “system preview” before the calculation is started.
- Even when point fixings are used, it is very important to get a uniform, fine mesh around the point fixings to guarantee the quality of the calculation.
- It may arise, that the mesh for point fixings can't be created. Then the element size must be slightly in- or decreased to achieve a well formed mesh.

6.2 Contact approaches

- Many calculations can be carried out with contact approaches.
- For separation of the two touching components, the program has to iterate to build a convergent solution.
- The definition of detachment takes place by considering the tolerance value. This tolerance describes the distance changes between the two parts until they uncouple. Basically: The stiffer one of the two components is, the smaller the tolerance must be chosen.
- Example:
 - o A plate lies upon a weak rubber strip with $E = 5 - 20 \text{ N/mm}^2$. A usable value for tolerance is 0.01mm.
 - o When a stiffer strip of plastic is used (e.g. POM with $E = 3000 \text{ N/mm}^2$) the tolerance shall be set to 0.0001mm.
 - o If the glass panel is lying even in direct contact to aluminium ($E = 70000 \text{ N/mm}^2$), the tolerance must be further decreased (e.g. 1.0e-6mm).
- Through detachment the static system may be changed. Attention must be paid to not achieve a unstable undetermined behaviour. To work against, springs can be used which must be defined in a way that they doesn't affect the mechanical system.

6.3 Calculations of insulated glass unit

- The calculation approaches here used, describe the exact boyle's law of gas and isn't an approximation.

- As well the gas rearrangements are considered, whereby the program needs in some cases up to approx. 200 iterations until the gas pressure inside the unit has been adjusted to the same value at any position.
- Pendulum impact calculations can be carried out for insulating glass units too.
- When point fixings are used in insulating units, automatically spacers are set at the bore hole rim. Therefore the definition in spacers will be used, even when no free edge has been selected! Regard the register card under: „Supports -> Spacer“. (see section “spacer”),

6.4 Proof of stresses

- For glass components the proof of stresses is done by comparing the maximum principal stresses with the allowed stresses due to the table below.
- These calculated values can be found in the protocol under the item „Maximum principal stresses“ and are listed there for each package.

Permissible principal stresses [N/mm²] : (German Standard)

Kind of glass	Horizontal glazing	Vertical glazing
heat toughened glass form float glass	50	50
heat toughened glass from cast glass	37	37
enamelled heat toughened glass form float glass *	30	30
heat strengthened glass	29	29
enamelled heat strengthened glass*	18	18
float glass	12	18
cast glass	8	10
laminated glass from Float glass	15 (25 ^{**})	22,5

* enamel on tension side

** is only for the bottom laminated glass of a horizontal insulating glass unit for the load case of failure for the upper glass panel allowed