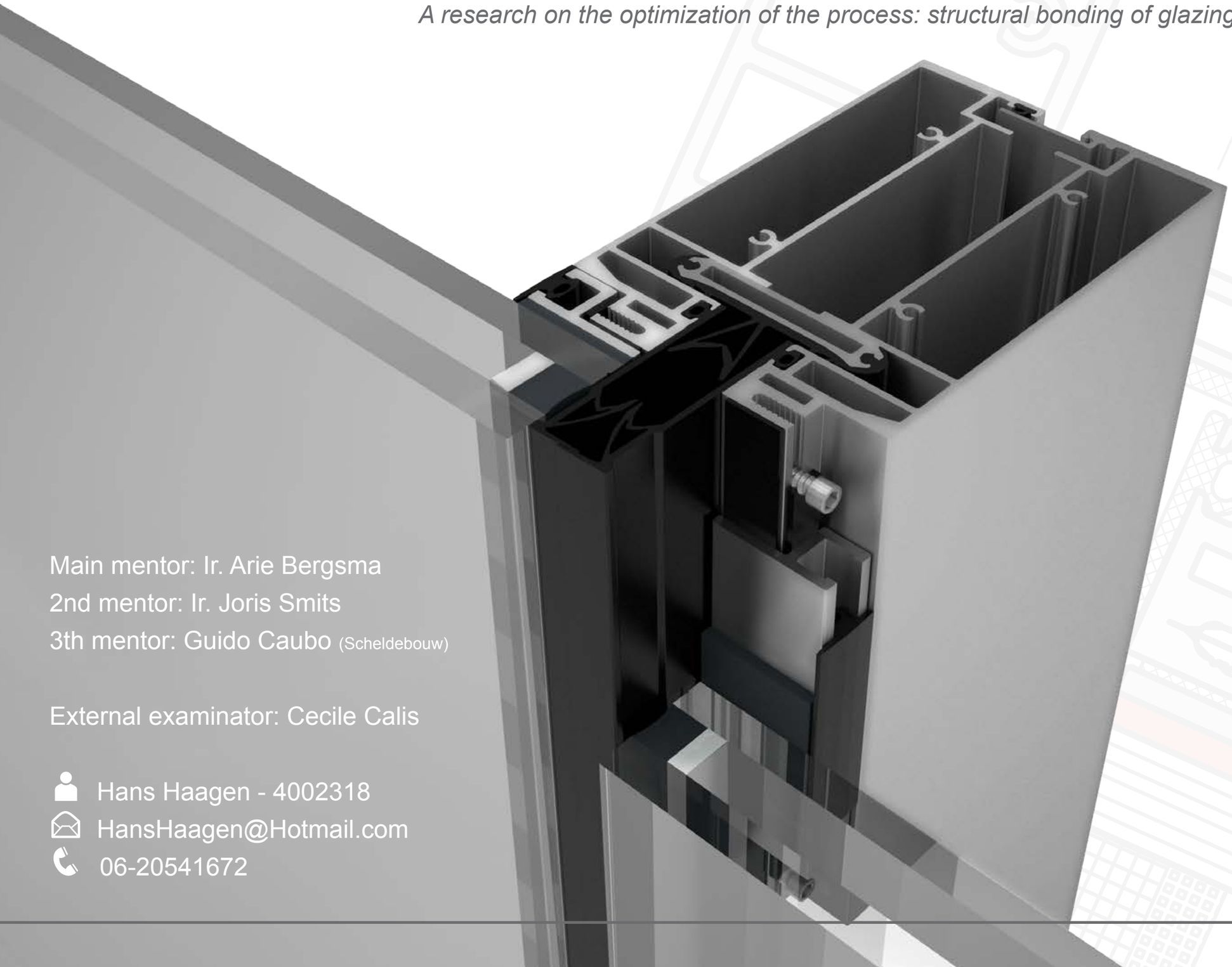
Final Presentation P5

Hans Haagen 4002318 - 4 July 2014

A research on the optimization of the process: structural bonding of glazing in unitized curtain wall facades.



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TU Delft Delft University of Technology

Presentation contents

- Introduction to structural bonding
- Topic definition
- Research
- Different approaches
- Design
- Evaluation
- Conclusion

- Introduction to structural bonding
- Topic
- Research
- Different approaches (short)
- Design
- Evaluation (with case study)
- Comparison
- Conclusion

Structural bonding

Definition and example

Definition of structural bonding

Structural bonding is the making of a bond that joins basic load-bearing parts of an assembly, by using a structural sealant / adhesive.

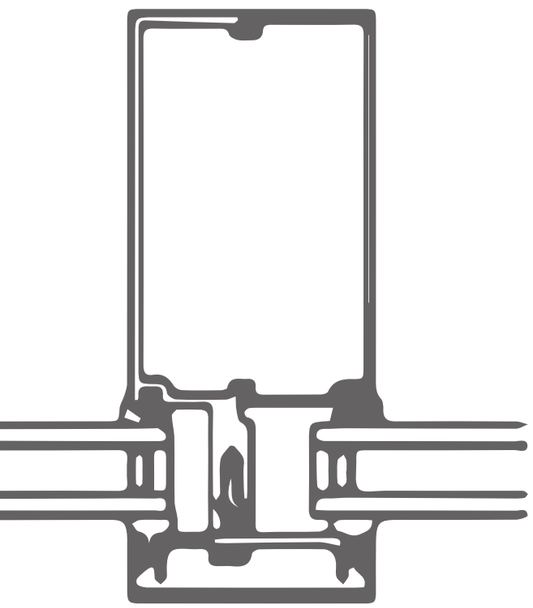
Introduction to structural bonding

Why?

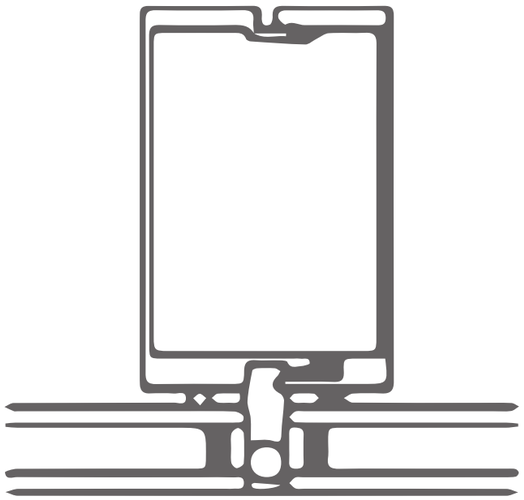
Reason to use

The flush detail, possible by structural bonding, is a much sought appearance in modern architecture. Also: good thermal and acoustic properties.

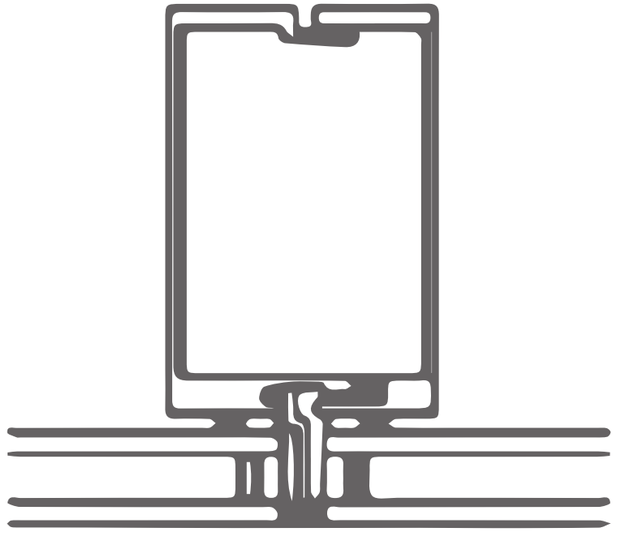
Mechanically fastened system



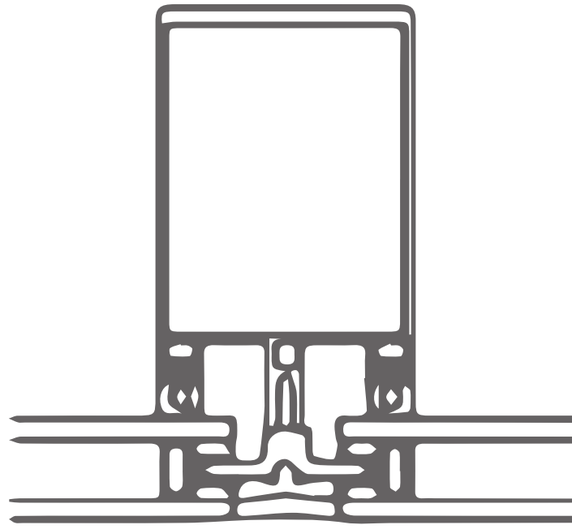
Structural glazed wet weatherseal



Structural glazed with gasket seal



Hybrid toggle glazing



A product of quality control

- *ETAG 002, Part 1, Part 2 and Part 3*
- *Cahier 3488 (France) Pass-Vec certification by CSTB*
- *EN and ASTM standards*
- *Permasteelisa Sika Procurement Contract including appendices*
- *'General Guidelines Structural Silicone Glazing with Sikasil® SG Adhesives'*

Procedure:

Step by step description of the essential steps in process. Compliance is essential to be able to assure the quality of this product.

(material properties, pre-treatment, properties of the adhesive/sealant, environment, etc.)

Types of adhesives

2-part silicone

- Extra essential step: the correct mixture of the 2-parts (sealant properties).

2-part silicone

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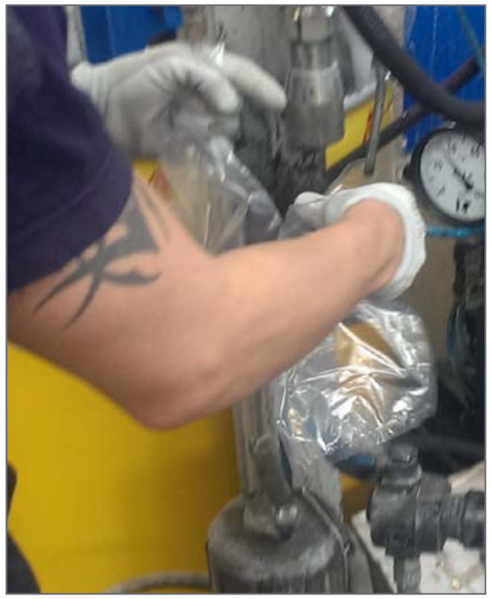
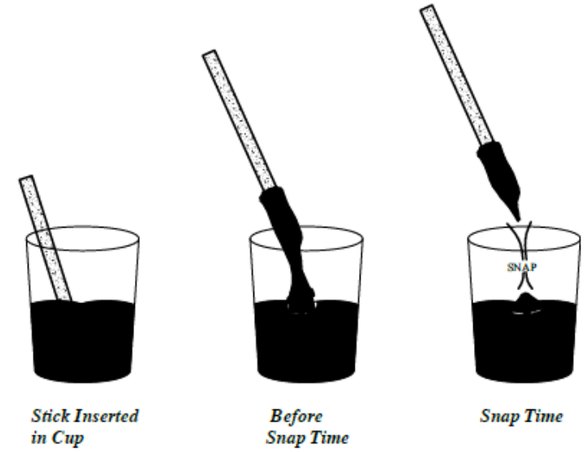


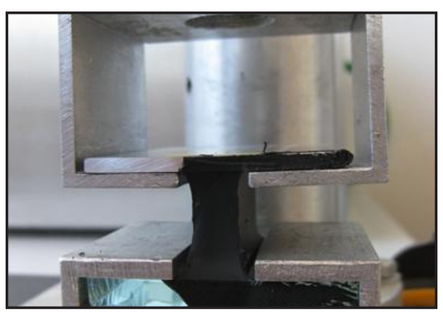
Taking mixing ratio sample from mixer



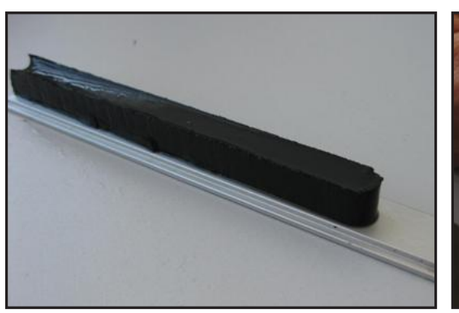
Snap time test

uniform black the mix **is good** **white streaks** the mix is **NOT good**.

Butterfly test



H-sample: tension test



Peel sample test: bonding test

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2-part silicone

- Extra essential step: the correct mixture of the 2-parts (sealant properties).

1-part silicone

+ Properties are fixed
- Long curing time
- Limited joint depth

Structural tape

+ Properties are fixed
+ Fast curing
+ Easier application
- Little/no experience

Less essential steps would mean a less extensive procedure …

Topic definition

Problem statement

Simple and good performing detail, yet, it demands extensive procedures.

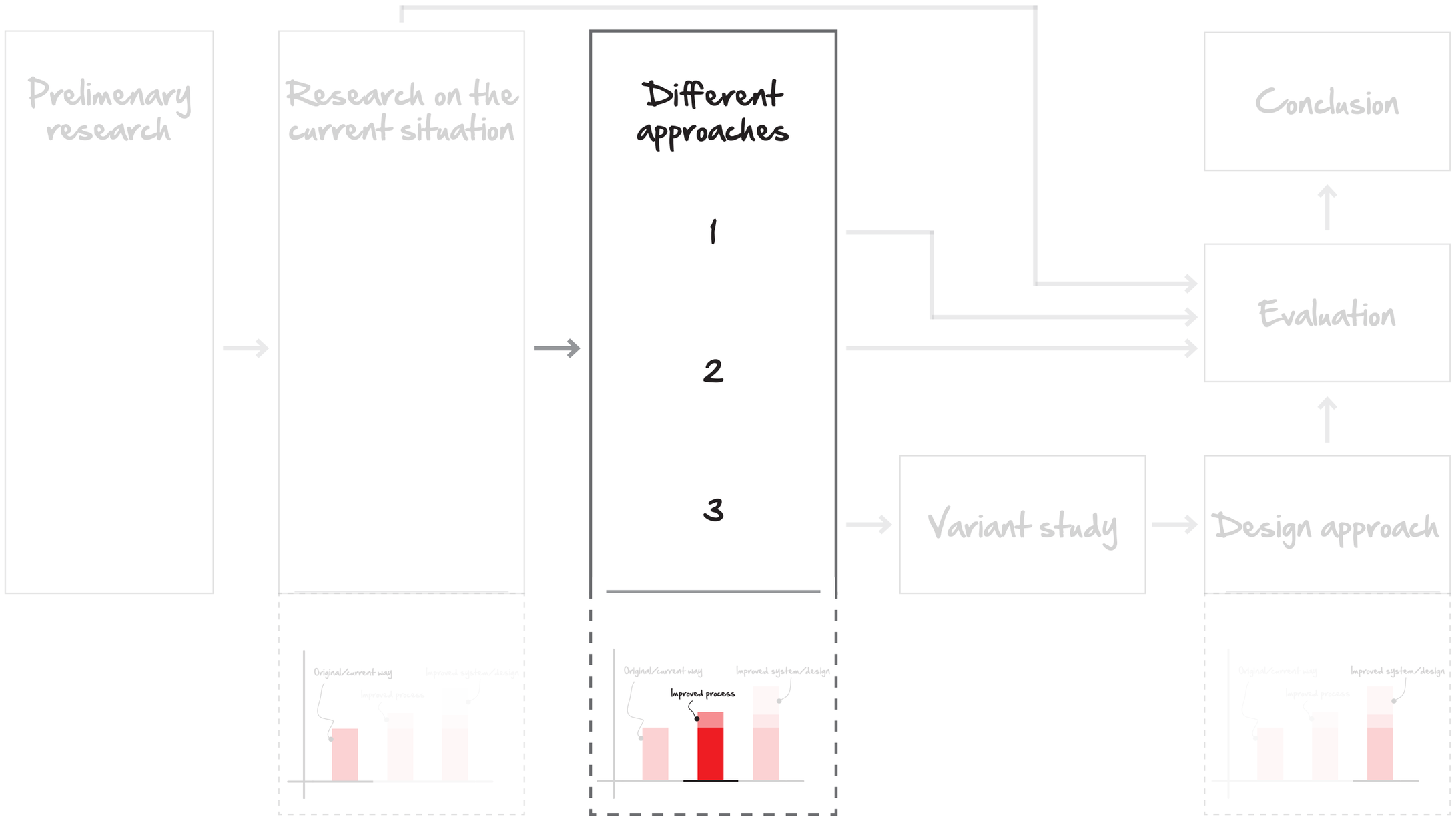
There might be reasons and possibilities to improve this.

” Because of the simplicity of the detail and cost driven nature, possible improvements could be disregarded because of a more complicated system and higher costs. ”

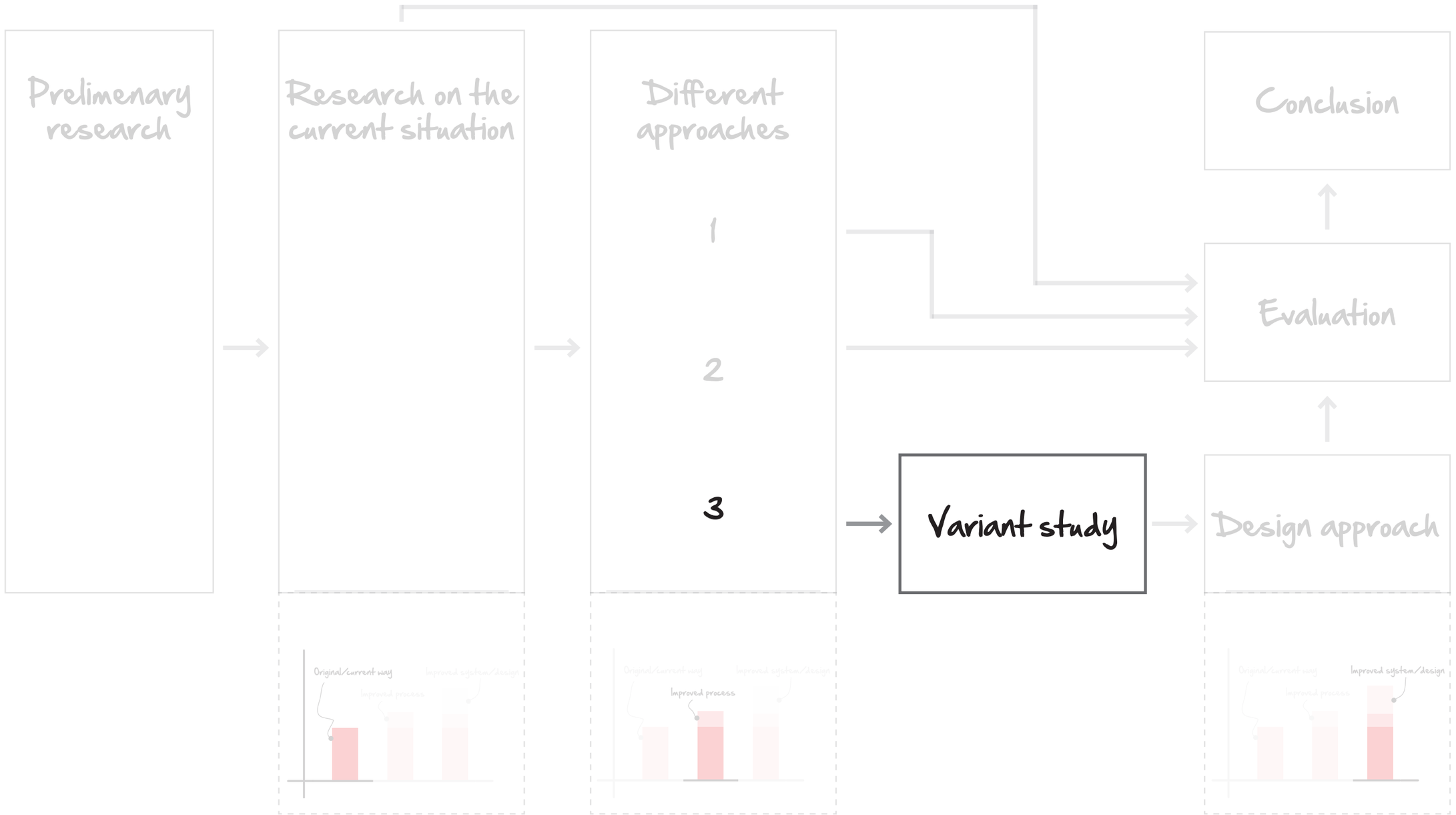
Research question

How can the process of structural bonding of glazing in unitized curtain wall facade systems be improved?

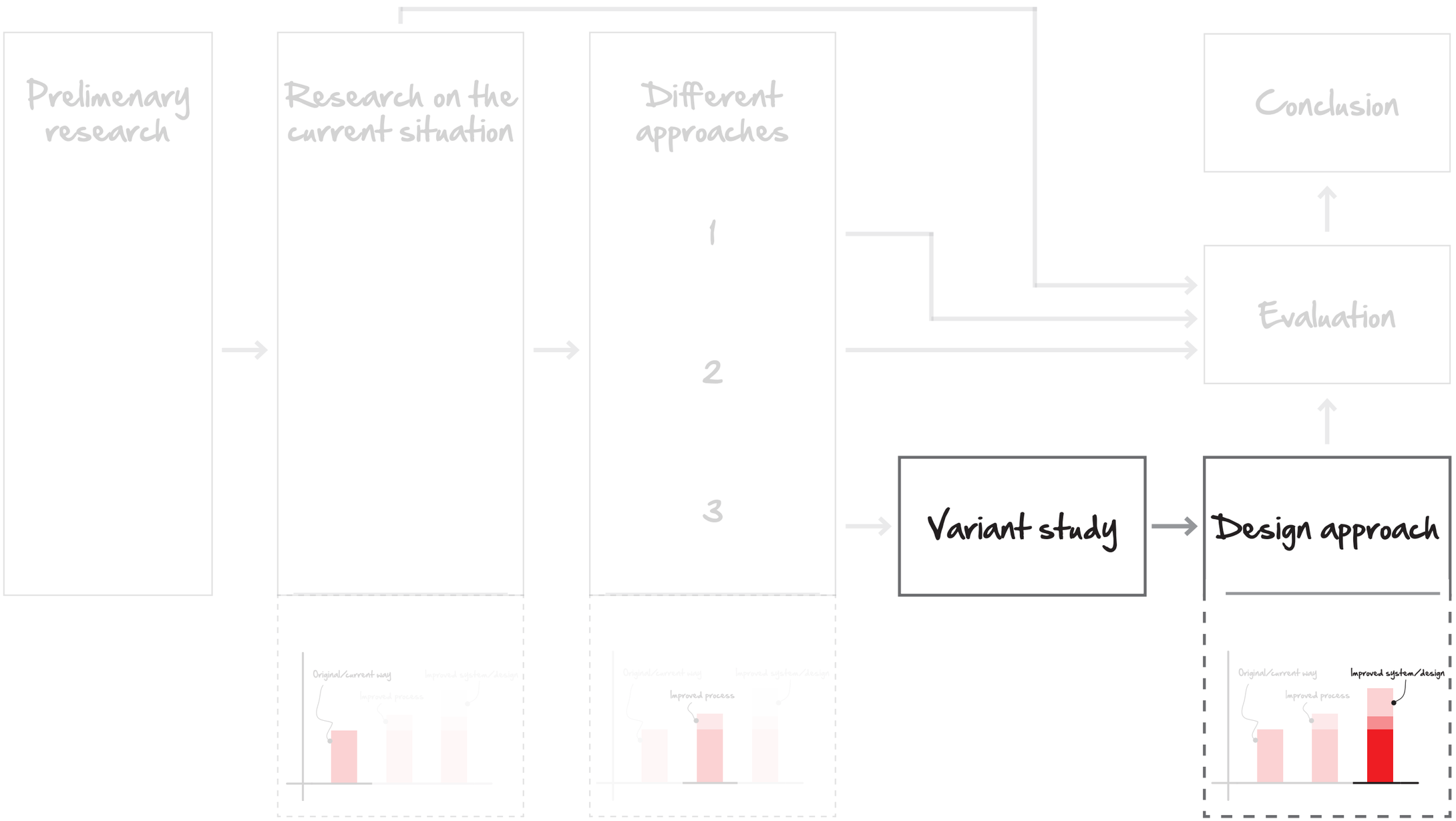
How and to what extend can the process be improved, merely on process level



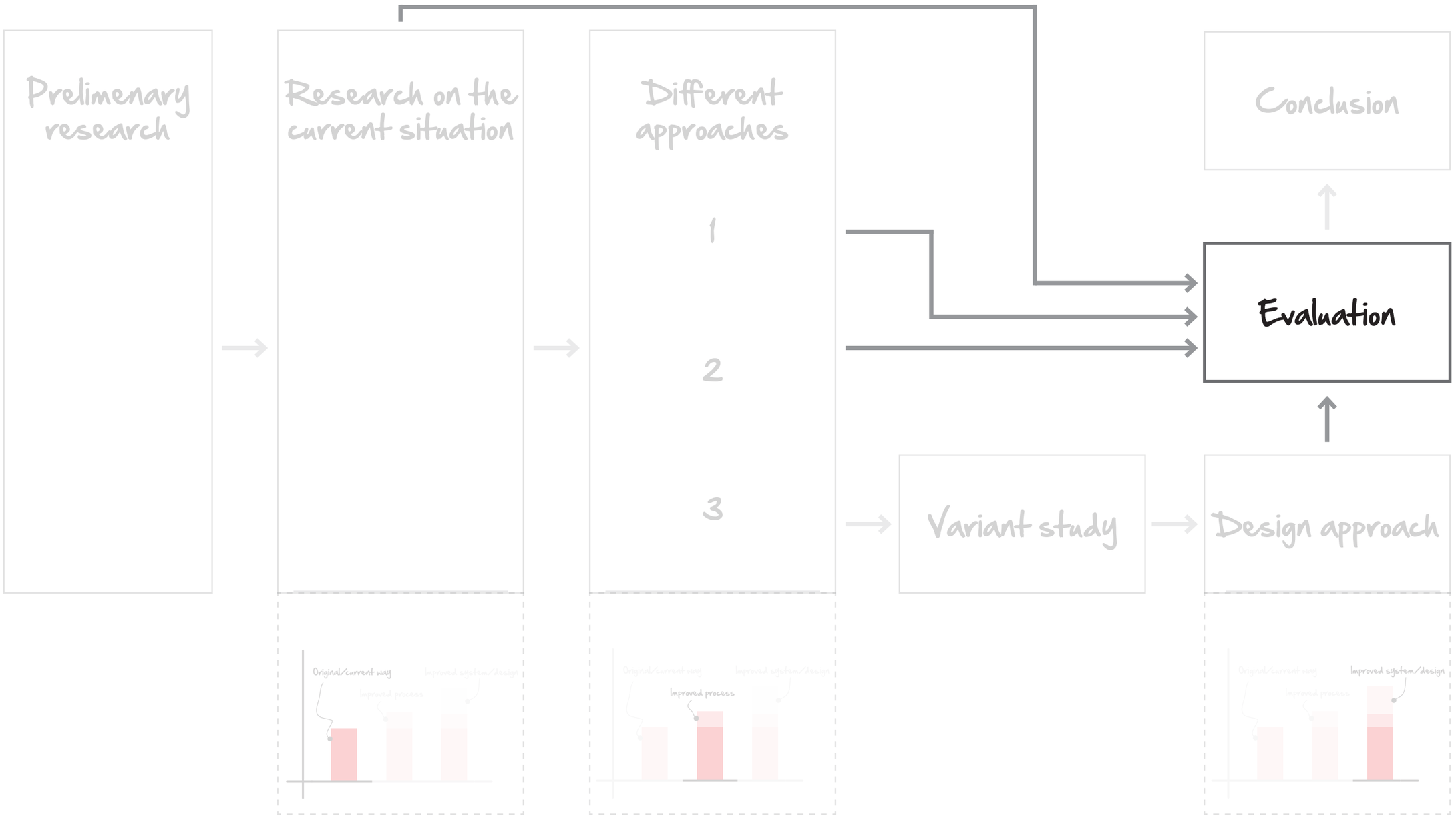
How and to what extend can the process be improved by implementing a new system and what should these improvements be



How could the detailing of such an improvement be



What reasons are there to change, or to not change, the current process? In other words: What benefits are needed to make a proposed improvement feasible?

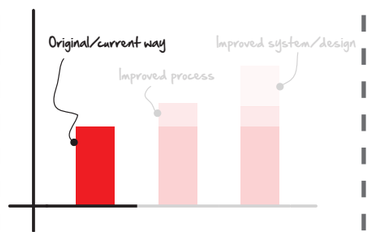


Methodology of research

Prelimenary research

Topic definition

Research on the current situation

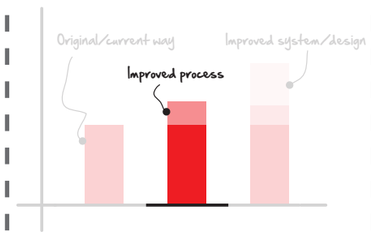


Different approaches

1

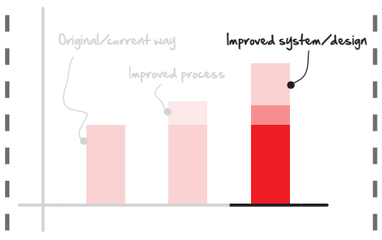
2

3



Variant study

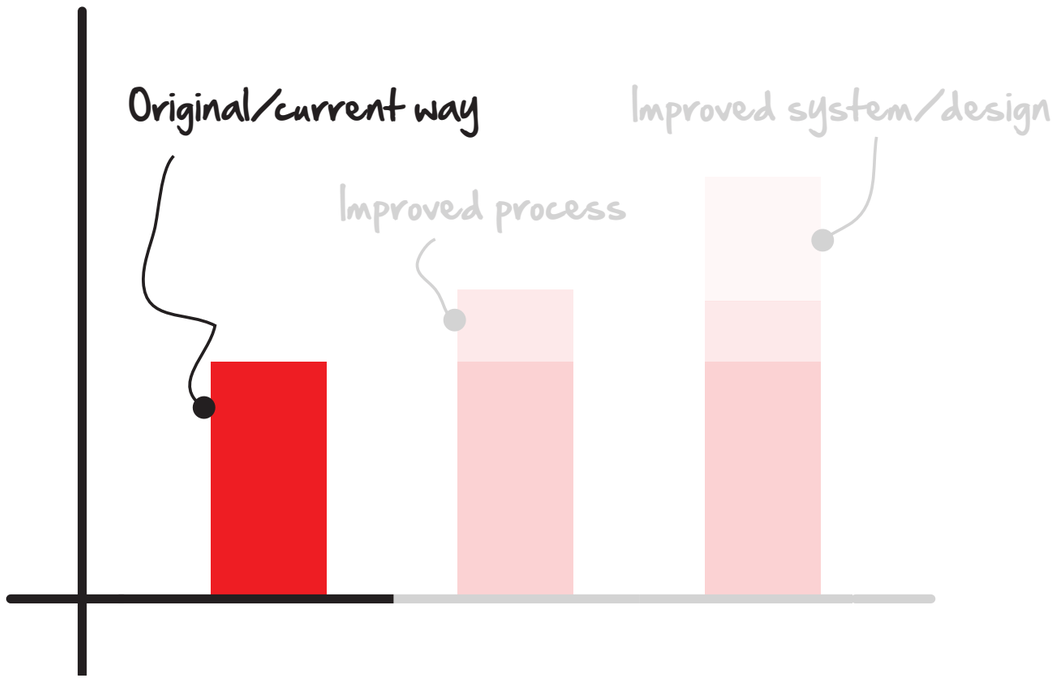
Design approach



Evaluation

Conclusion

Research


Original/current way
Improved process
Improved system/design

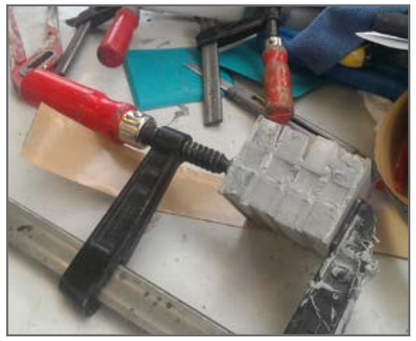
Research

Content

Interviews	- Introduction in the process
Process Analysis	- Procedure analysis - Working in production - Contact with other industries
Stakeholders Analysis	- Overview in interests
Design analysis	- SWOT analysis of the basic system

Identification of opportunities and interests

Working in production



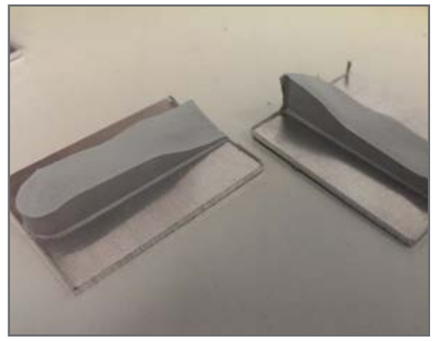
Overall produceability

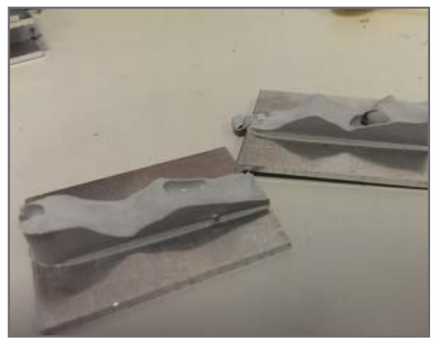
Working in production

Overall produceability

Research

Working in production

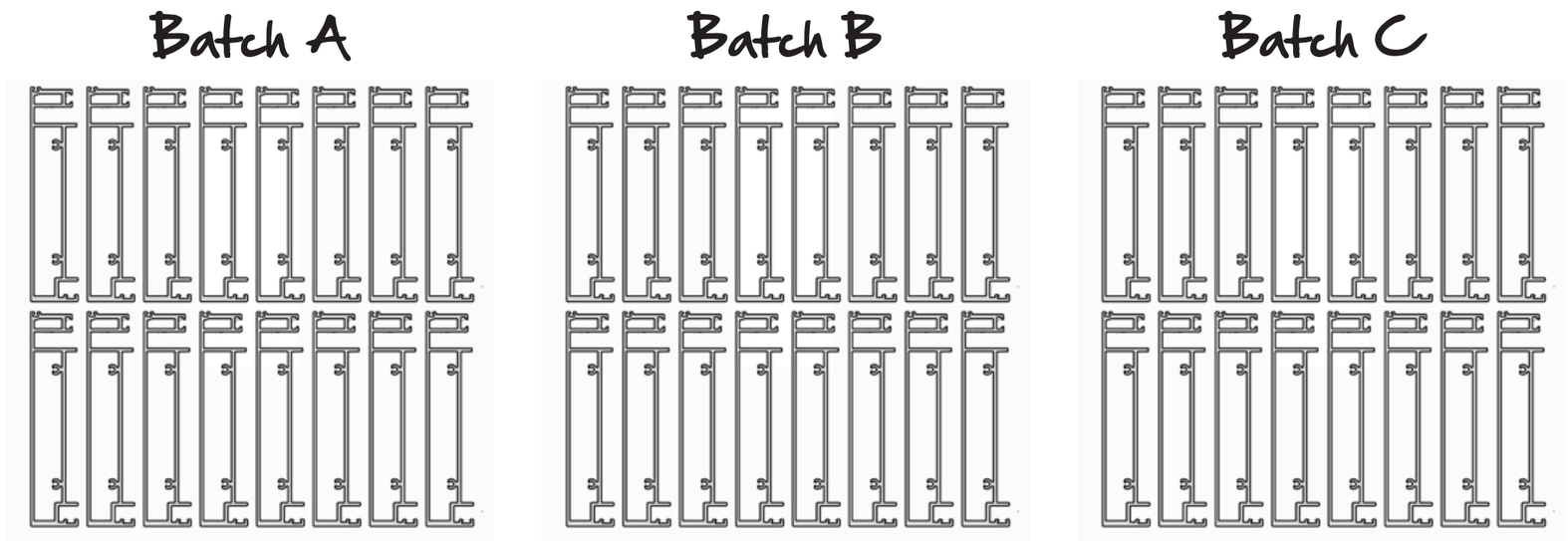


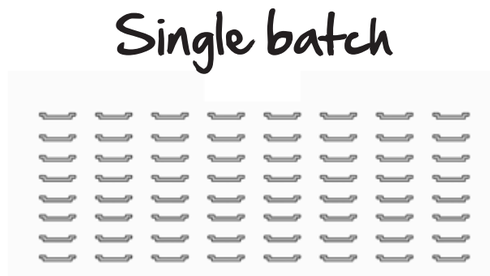


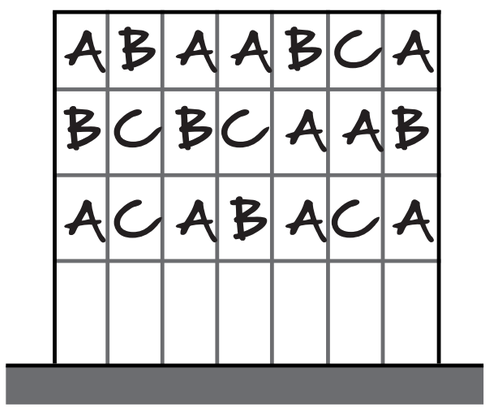
→ Overall produceability

Procedure analysis – e.g. traceability

Tests should be done on each batch of anodised aluminium (e.g. group of aluminium profiles anodised in the same bath at the same time for one day maximum).







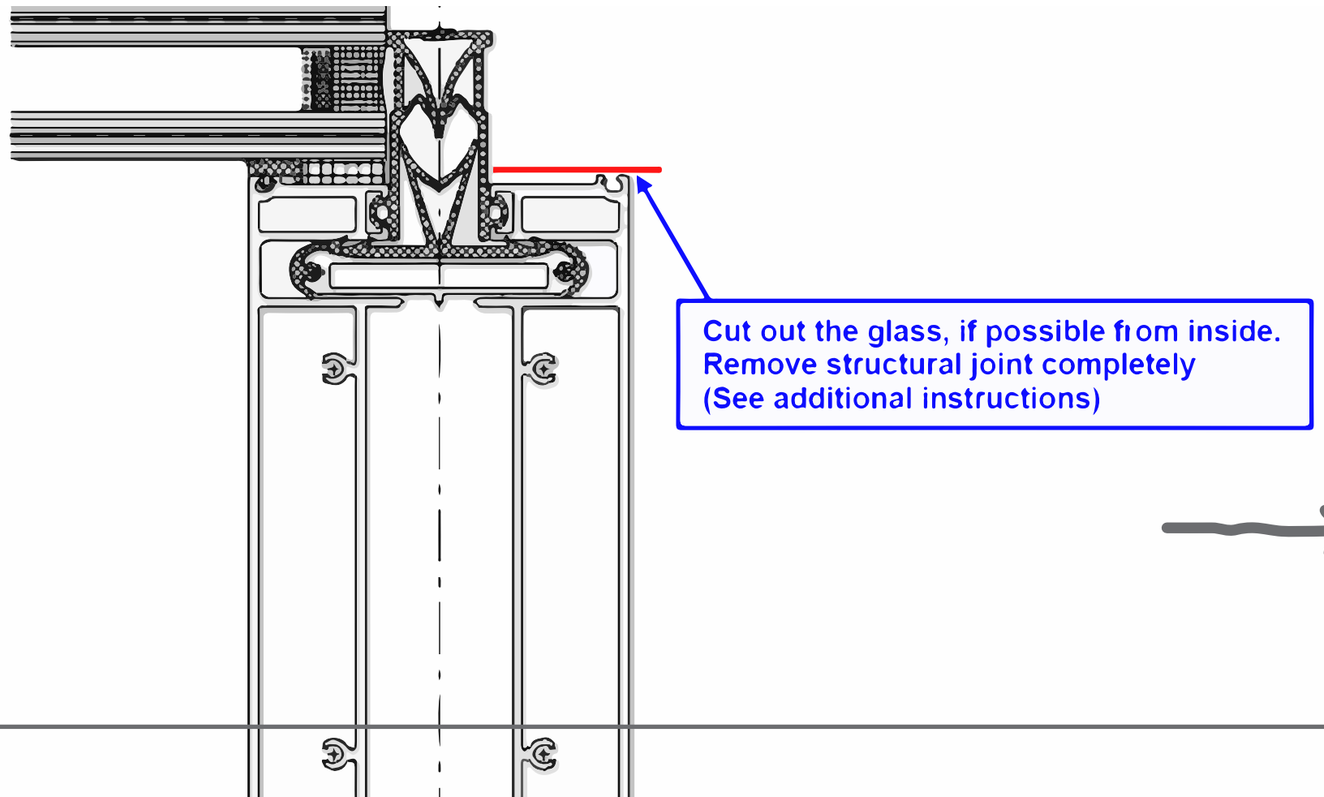
Advantages:

- *Less administration*
- *Less complications in case of a failure*
- *Unitisation of the process*

→ Exclusion of profile tracing

Design analysis

Due to the difficulty of quality control during on site repair, a factory-glazed replacement frame must be installed. Therefore, it is necessary to make an assessment and to comment on the ease of future replacement.



→ Factory bonded replacement

Automotive industry

Consistent properties in the projects?

Automotive		Scheldebouw	
Surface 1	√	Surface 1	?
Surface 2	√	Surface 2	?
Sealant	√	Sealant	√
Procedure	√	Procedure	?

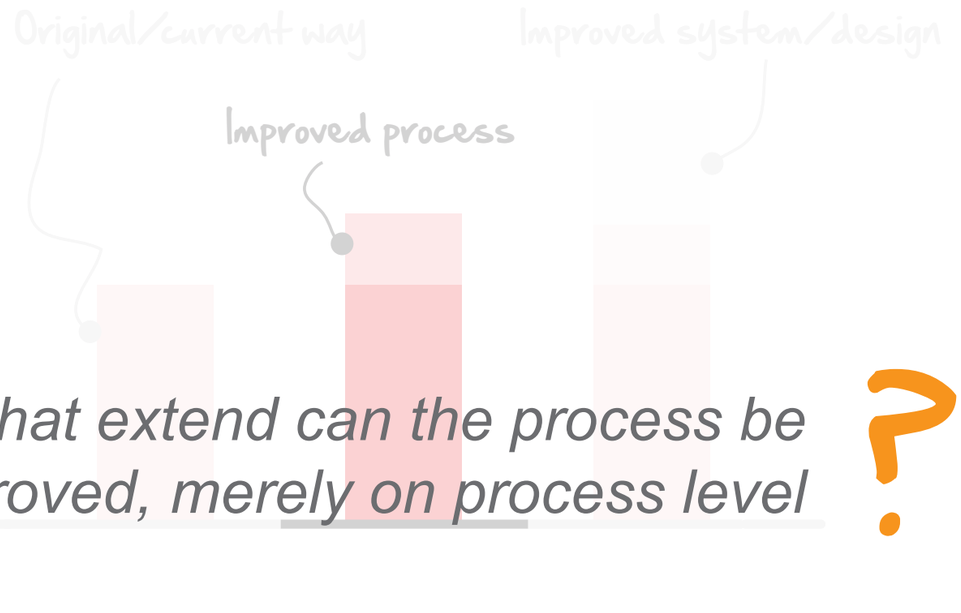
→ Process unitisation

Conclusions

Concluding from the research, improvement should be in:

- Overall produceability *(working in production)*
- Exclusion of profile tracing *(procedure analysis)*
- Replacement *(design analysis)*
- Process unitisation *(other industries / automotive)*
- Less extensive procedure *(multiple)*

Different approaches



How and to what extend can the process be improved, merely on process level

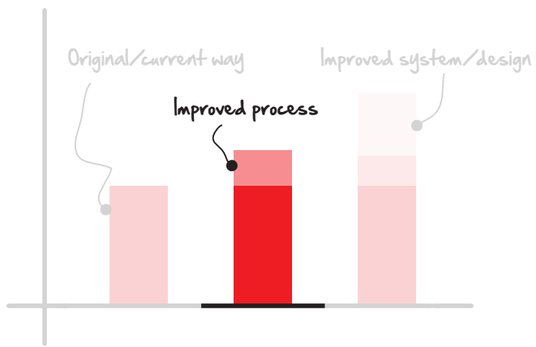
?

Approaches

[1] **When current contractual relations and guidelines are respected.**

Limitations:

- No/little experimentation or innovation because of limitations by the contractualrelations and guidelines.
- Tests and procedure imposed by Sika
- Only SG-500/550 and SG-20 by Sika are the products to use.



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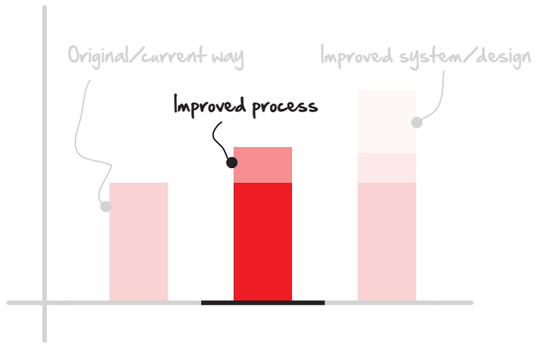
Possible improvements:
- Digitalisation of documentation for the procedure
- Practical aspects in production like the proximity of hygrometer and thermometer
- Create a basic work flow, in accordance with SIKA. This based on a standard glueing surface, also used for traceability. Unitisastion
- Outsourcing
- Exclusion of the tracing of profiles
- Solution for no on-site bonding. Replacement
- The use of 1-part silicone when possible



Remarks:
Least intrusive measures. Procedure and contractual relations can be kept, and process is still improved.

When time is available and the joint does not exceed 15 mm

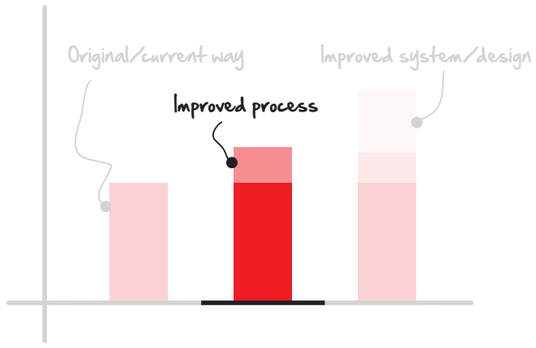
1-part silicone

+ Properties are fixed
- Long curing time
- Limited joint depth

[2] **When the current procedure, based on guidelines and Sika is disregarded.**

Limitations:

- Only sikasil SG-500/550 and SG-20 by Sika are the products to use.
- Contractual demands by client. They might ask for compliance with the ETAG and/or other guideliness.
- No guidance, needs own development of a system for quality assurance and trust by client.



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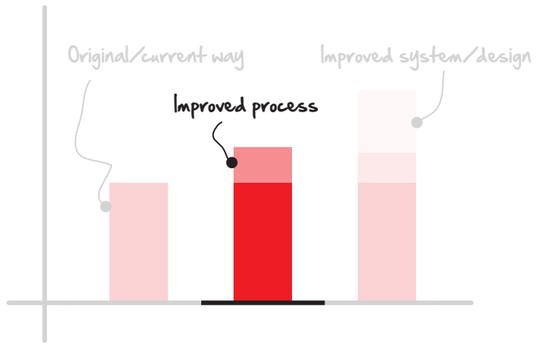
Improvements:

- Other ways of testing, e.g. non-destructive testing in stead of the other tests.
- Own quality assurance system.



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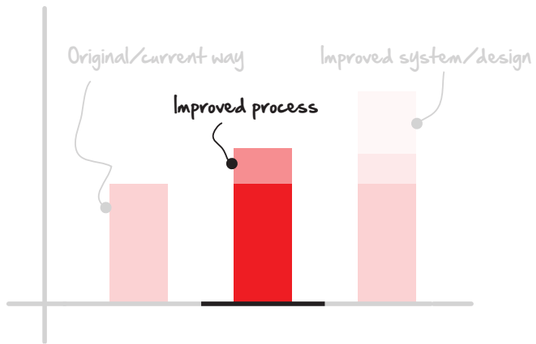
- No guidance, needs own development of a system for quality assurance and trust by client.

Improvements:
- Other ways of testing, e.g. non-destructive testing in stead of the other tests.
- Own quality assurance system.

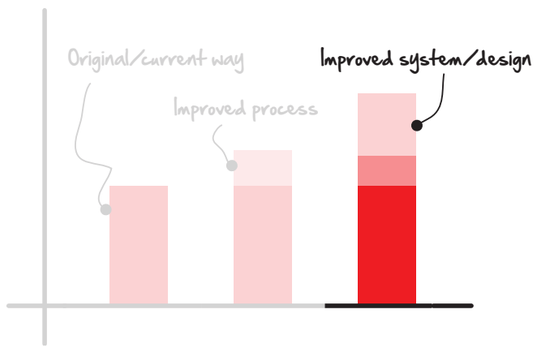
Remarks:
Still procedures need to be followed to assure the quality of the product.
When using a 2-part silicone it is important to assure the correct mixing.
Therefore, this will not improve a lot.



[3] **When the current provider of sealant (Sika) is disregarded or influenced.**

Limitations:

- Obtaining warranty from the supplier, if working with sealants, or take risks.



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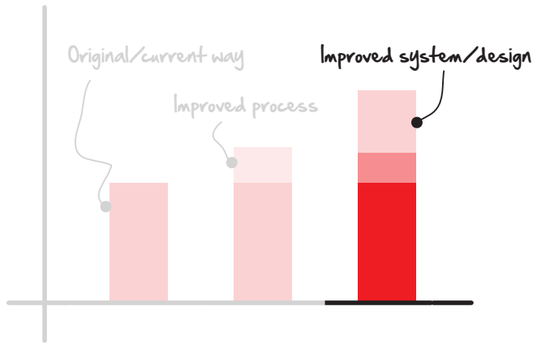
Improvements:

- Other types of fixation
- Other types of tests



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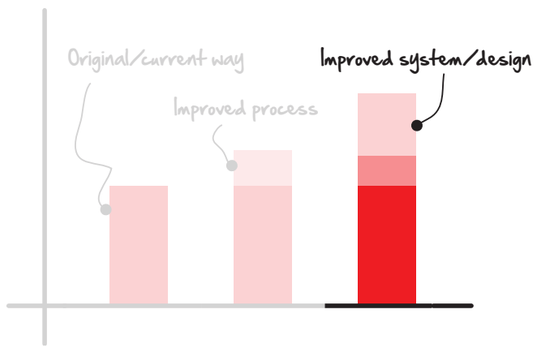
Improvements:

- Other types of fixation
- Other types of tests

Remarks:

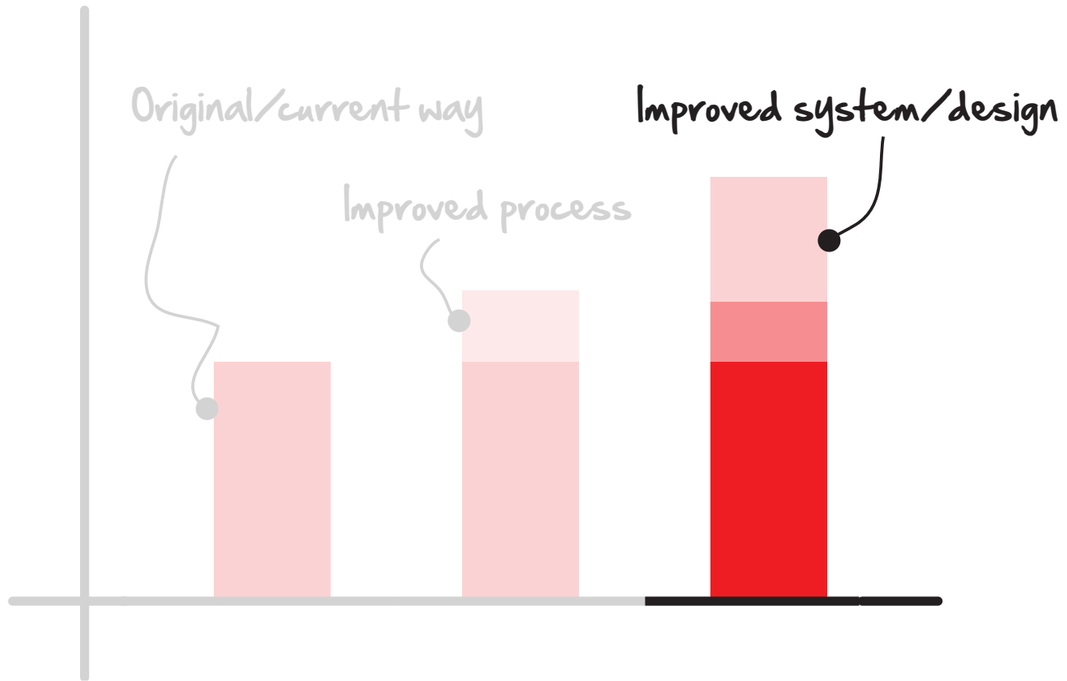
Requires a whole new warranty system with new contractual relationships with new suppliers or an ‘automotive‘ like system where the product for fixation is trusted by tests. In that case no extensive warranty system would be required. Yet, this might still be a too big risk to take.



Factors of influence

- Aesthetics
- Performance
- Production
- Waste / sustainability
- Costs (labour and material)
- Quality assurance
- Process flow
- Warranty

Design



Design
Improvements

Concluding from the research, improvement should be in:

- Overall produceability
- Less complicated quality assurance
- Exclusion of profile tracing
- Replacement
- Process unitisation

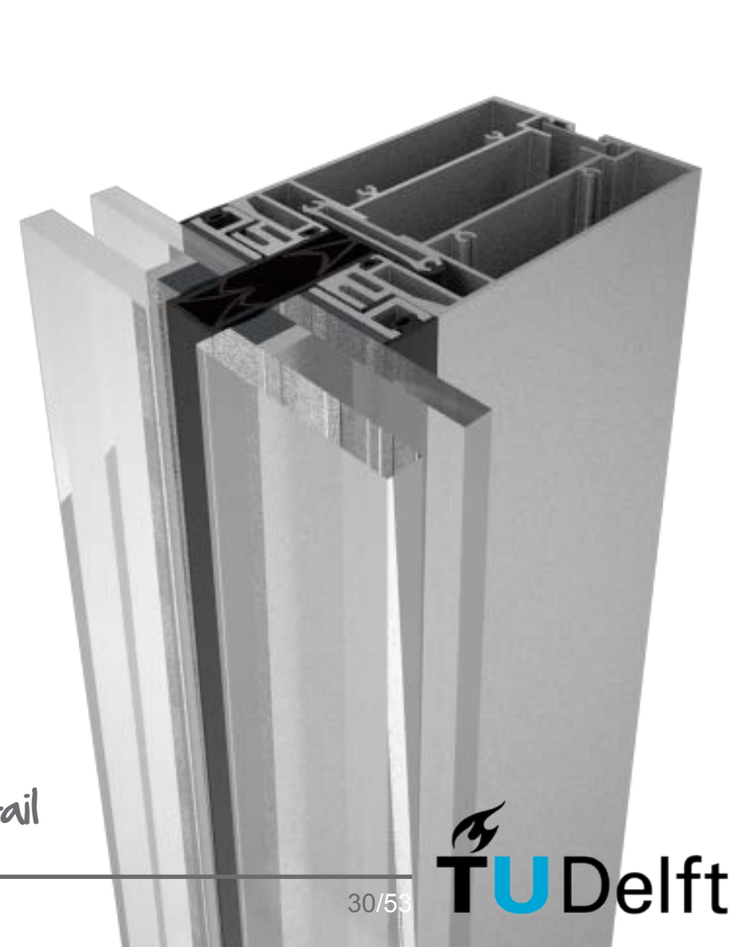
How and to what extend can the process be improved by implementing a new system and what should these improvements be

Design

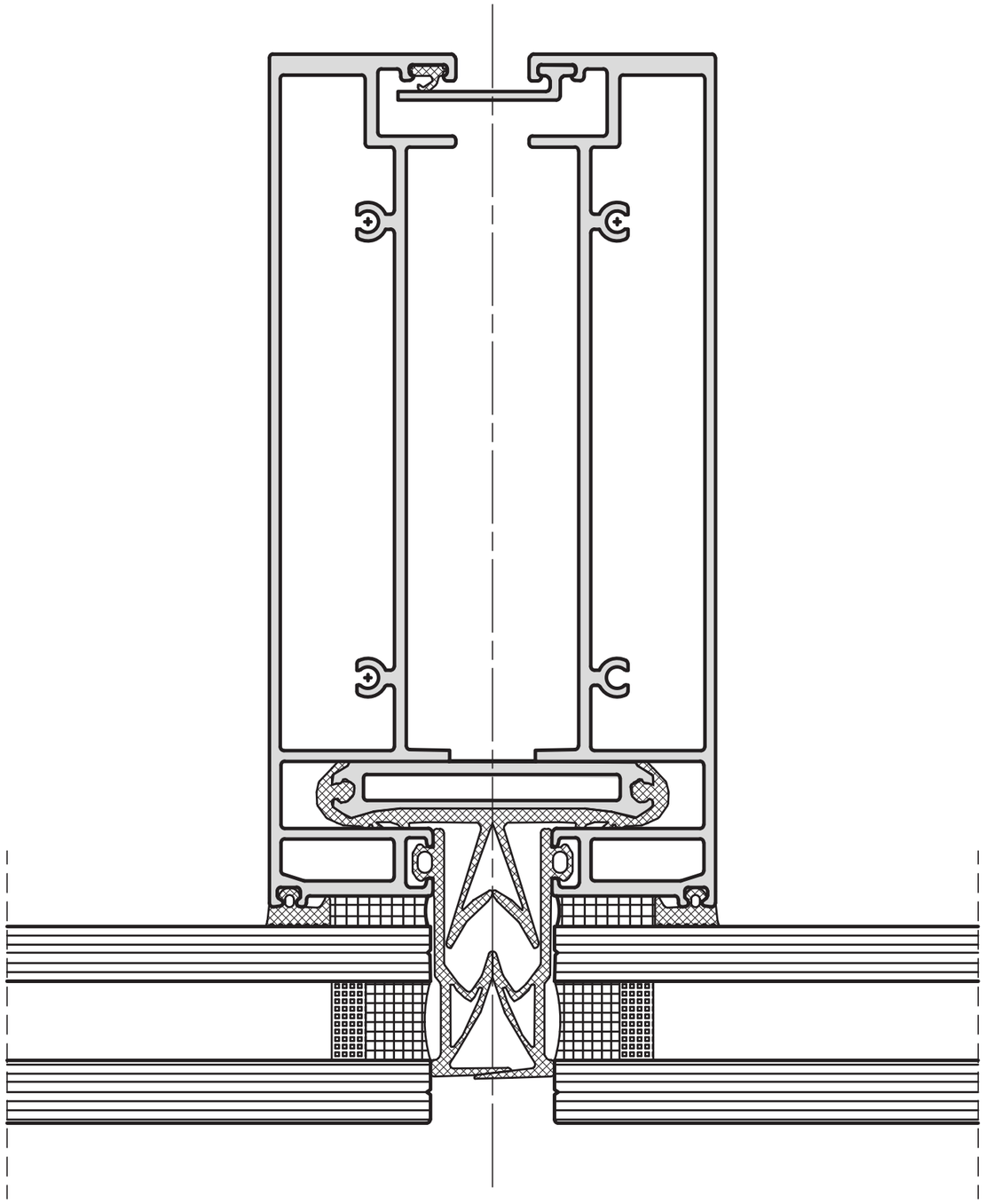
Variant study

- Slider profile (adaption to the design)
- Partial framing (adaption to the design)
- Quaternario profile (adaption to the design)

- Structural tape (adaption in method)



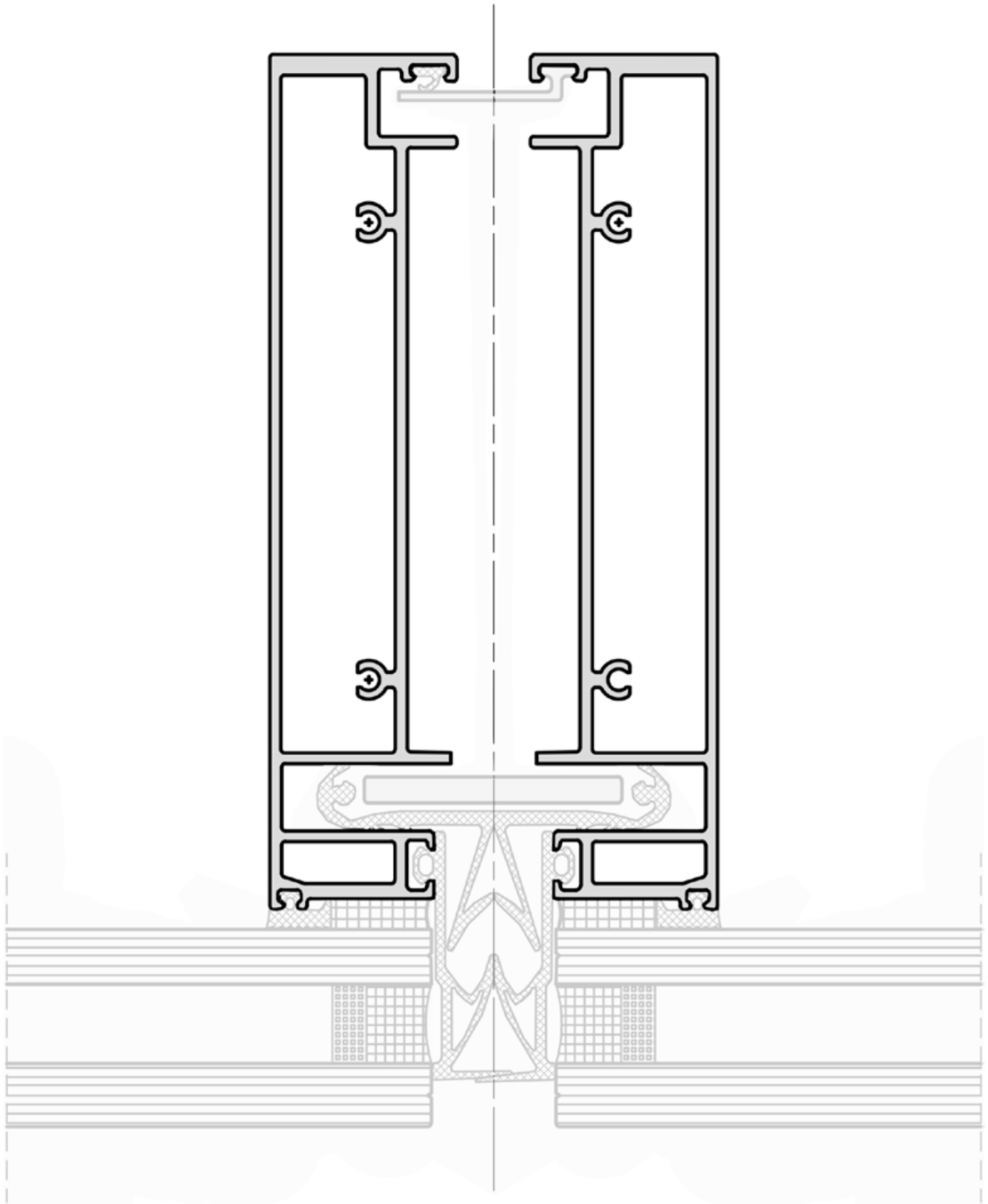
Mullion detail



Basic system

Description:

- Half-frame system. Tolerances!
- Gasket for sealant retention



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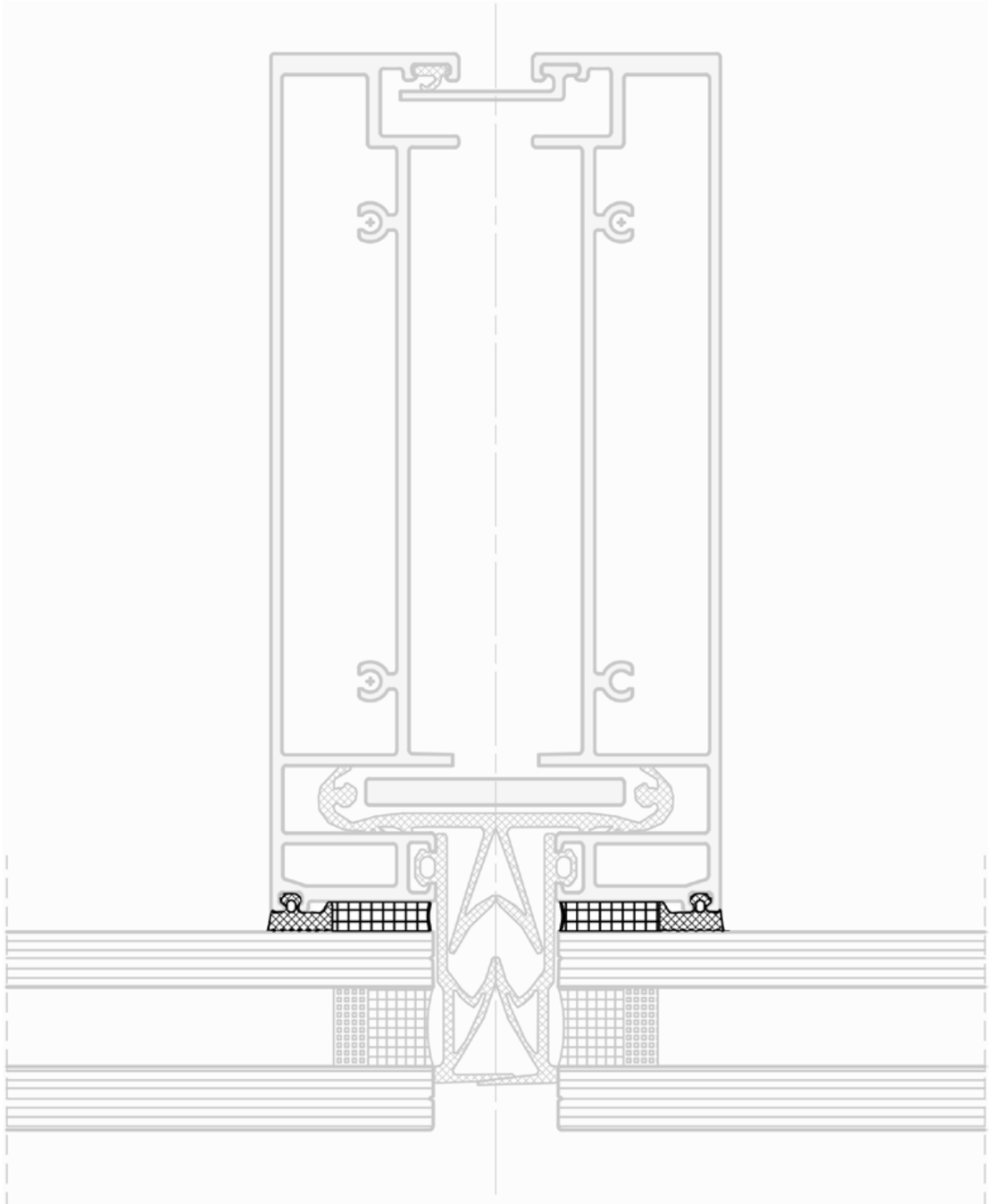

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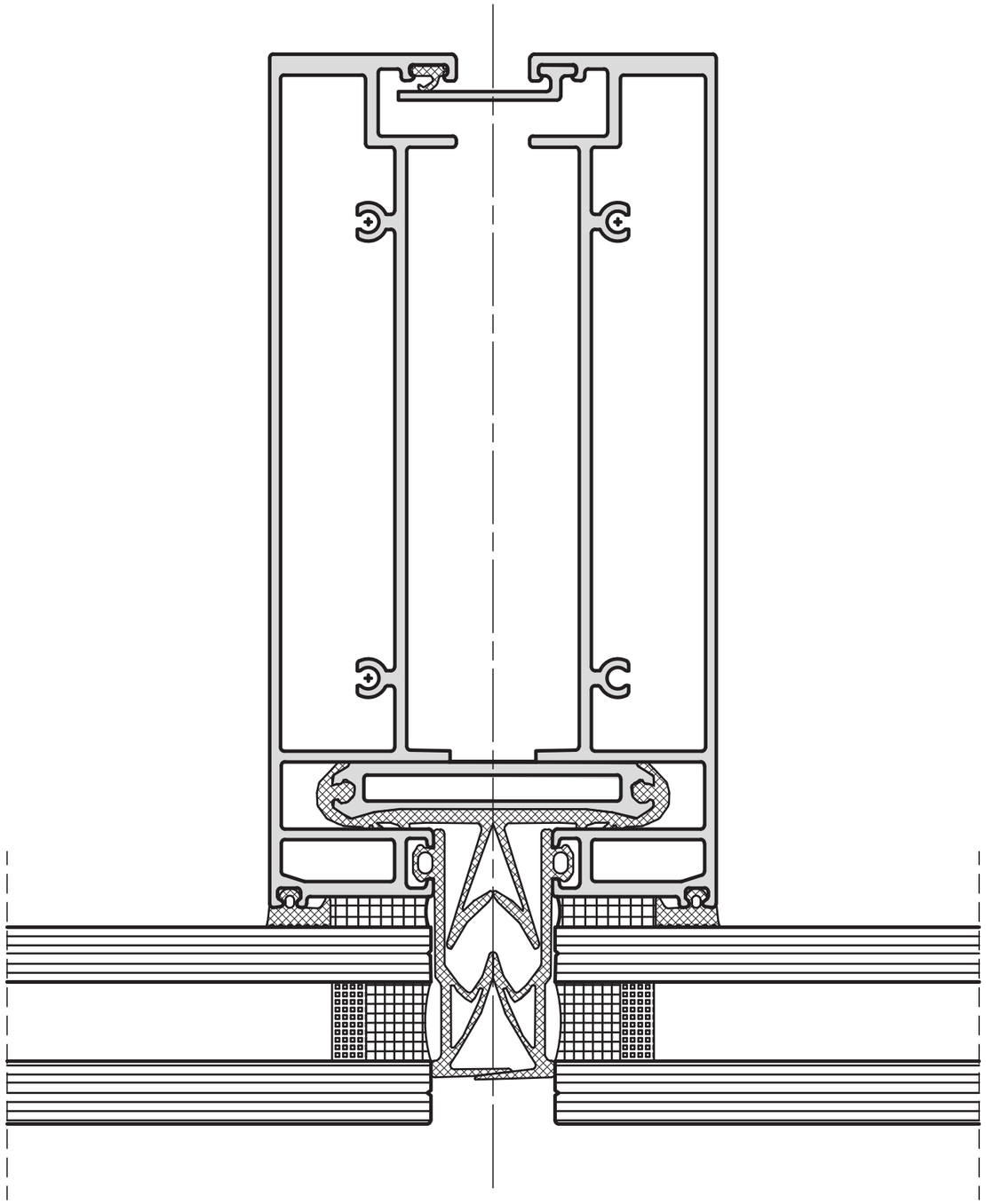


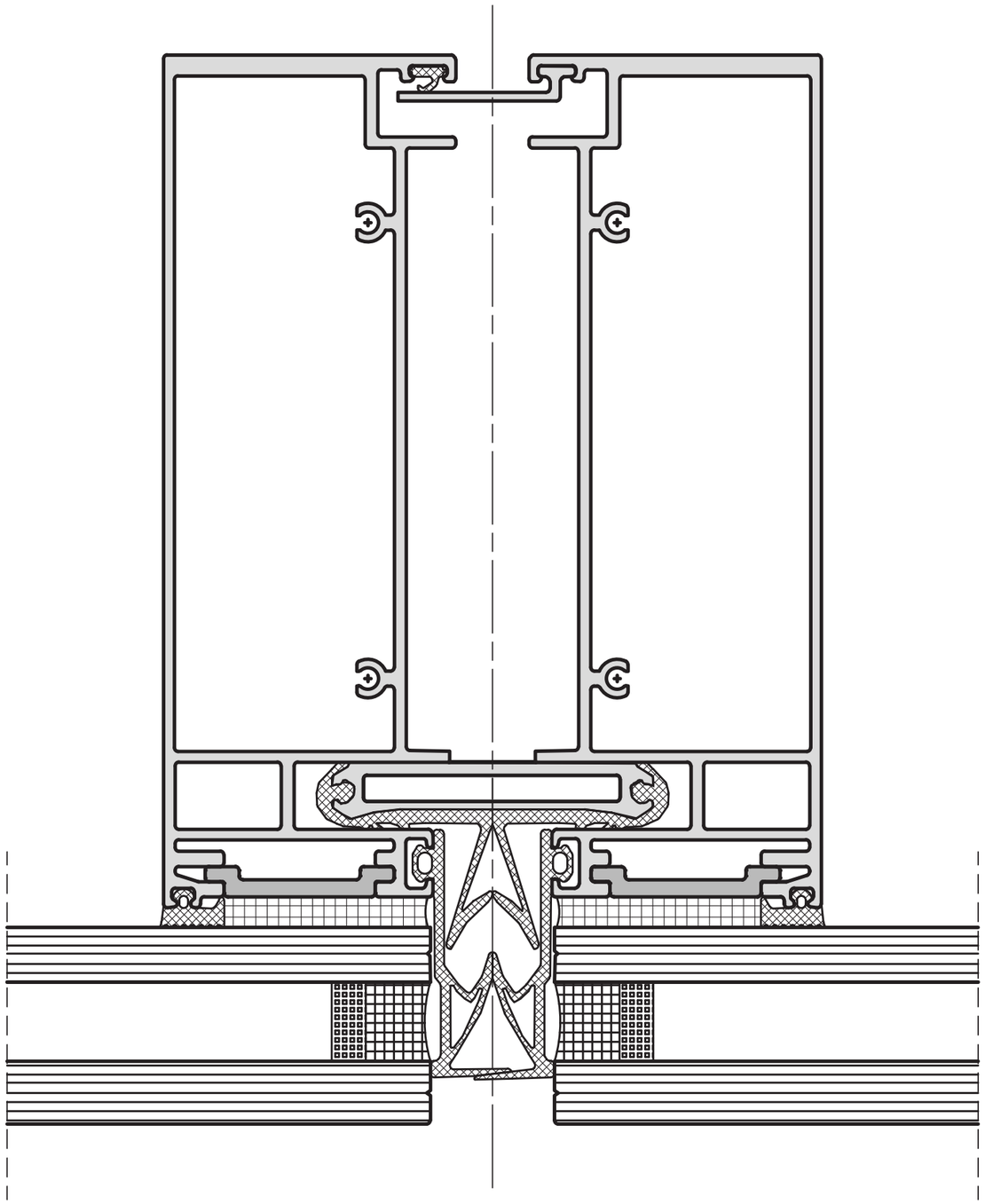
Basic system

Advantages:

- Simple detail with minimum amount of components
- Minimal thermal bridging

Challenges and disadvantages:

- Factory replacement is not possible
- Multiple profile batches in a project, caused by the size of this profile. Batches need to be traced throughout the project
- Application and processing of the wet 2-part silicone sealant



Slider profile

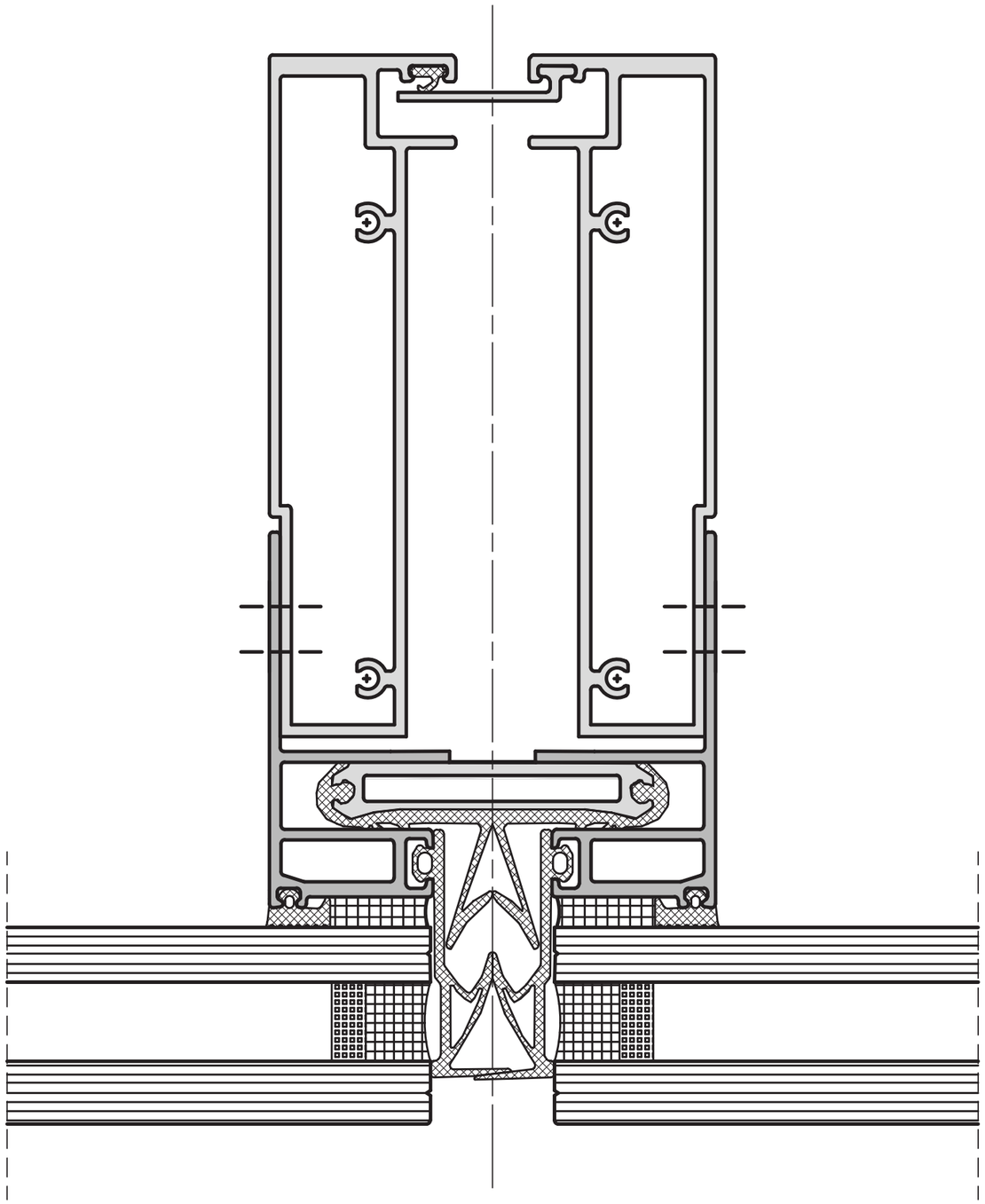
Advantages:

- Simple detail with minimum amount of components
- Minimal thermal bridging
- One batch in a project is possible because of the small insert. Therefore, this does not have to be traced throughout the project.

Challenges and disadvantages:

- Factory replacement is not possible
- Application and processing of the wet 2-part silicone sealant
- Extra component will bring extra costs in material and labour.

Very good option for the exclusion of profile tracing



Partial framing

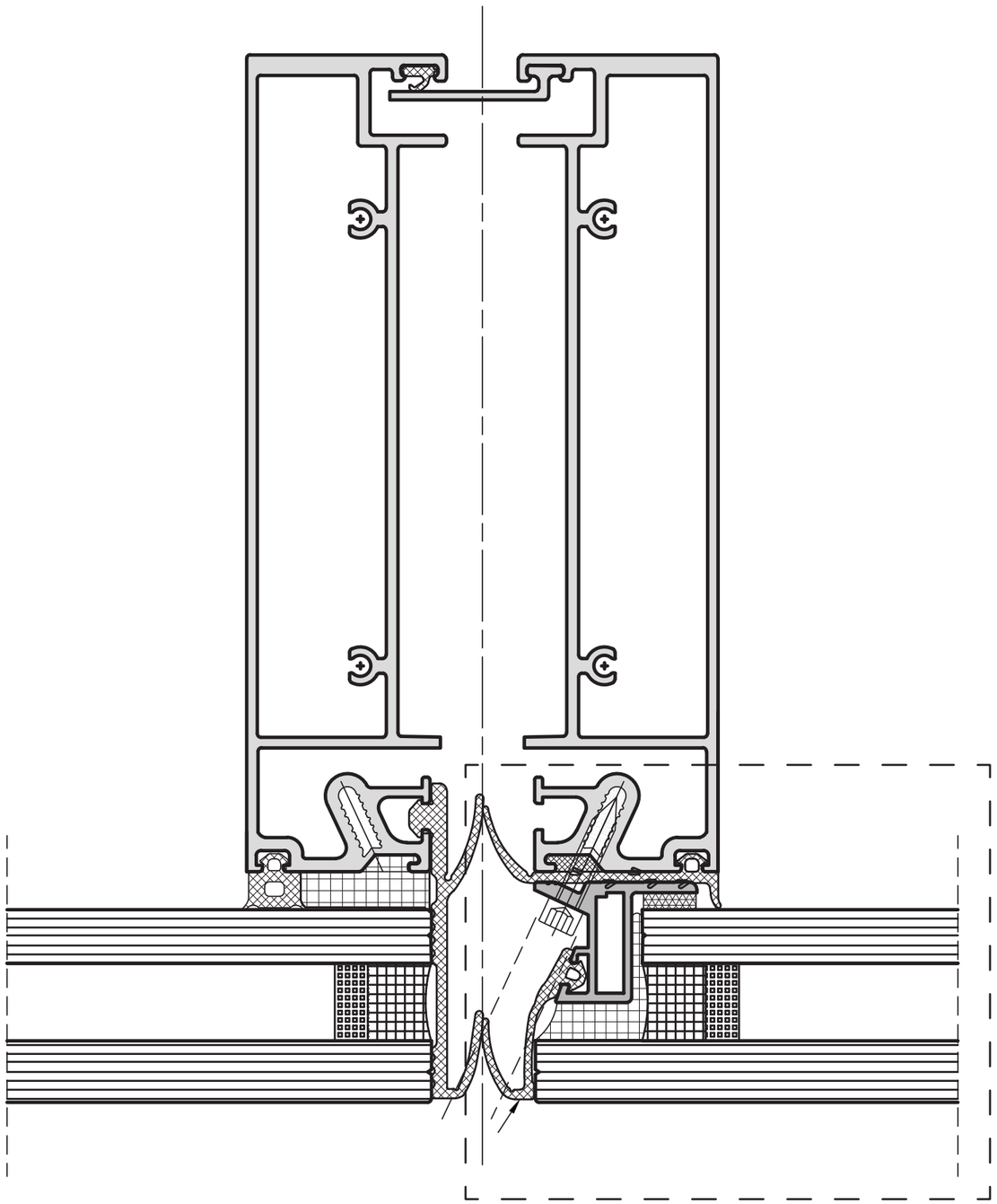
Advantages:

- Minimal thermal bridging
- Large batch in a project is possible. Yet, This is a bigger and more complicated insert than the slider profile
- Replaceable

Challenges and disadvantages:

- Double work: mechanical fixation *and a* structural bond
- Tolerances with replacement of an element
- Visible connection on the inside. Probable architectural disapproval

Not a very good option, but is a variant that improves both on factory bonded replacement and the tracing.



Replacement

Quaternario profile

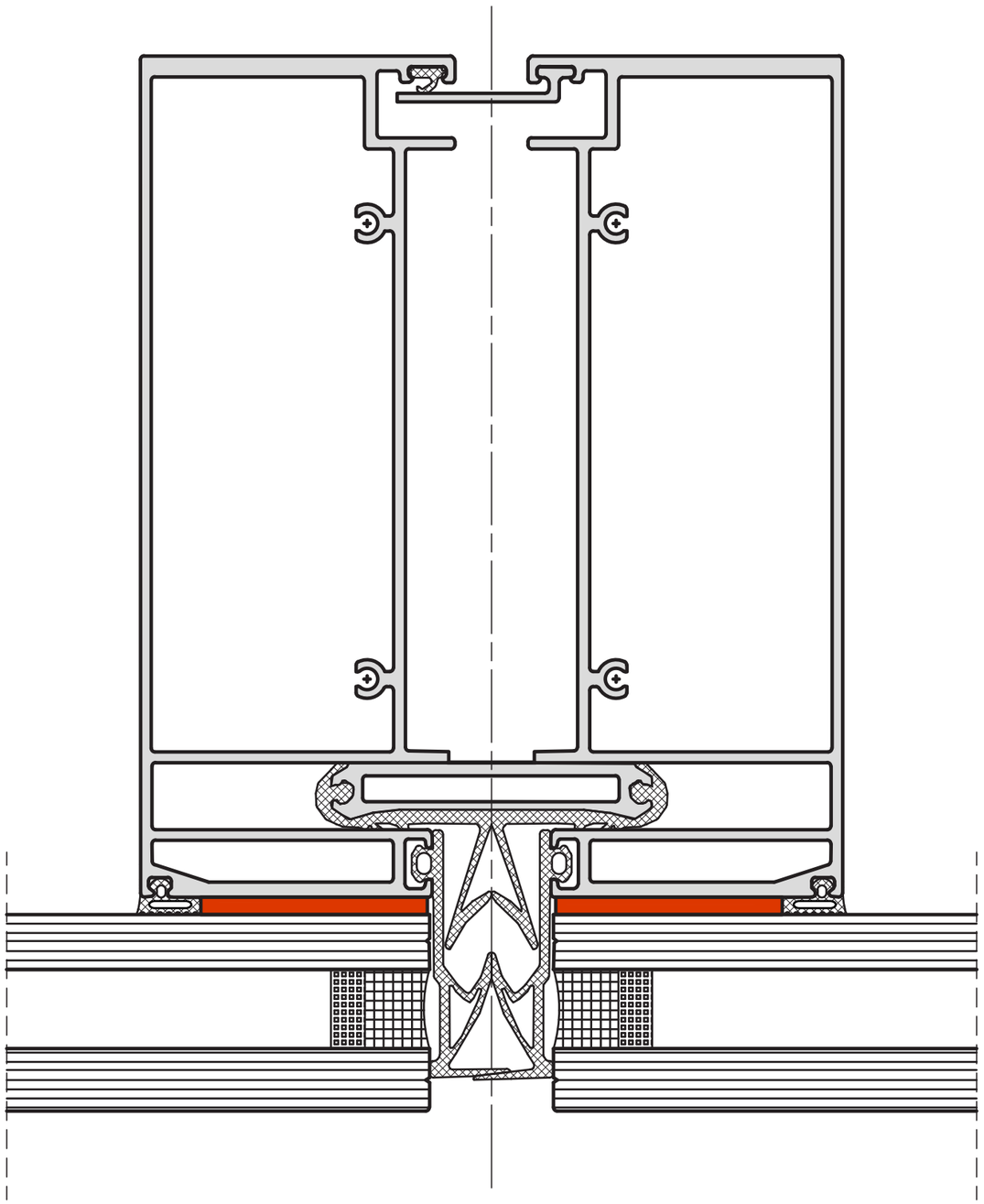
Advantages:

- Factory bonded replacement is possible
- No extra parts/cost in the first place

Challenges and disadvantages:

- In first instance it is not a solution for the tracing issue
- Stepped glass is needed for replacement which is significantly more expensive. Yet, only a little amount is replaced.
- For replacement, special glass needs to be ordered that requires special operation
- Wider non-transparent border when replaced. Visual difference with the other panels
- Less thermal insulation when replaced

Is a good and option for replacement. Yet, it does not solve the traceability issue and the replaced glass has some downsides like differing look and less thermal insulation.



Structural tape: 3M™ VHB™ Tape

Advantages:

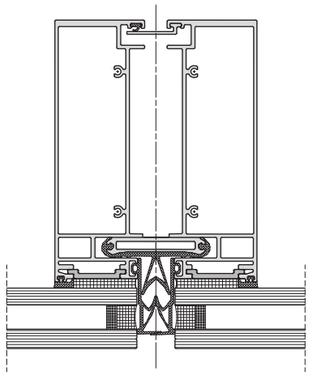
- Simple detail
- Immediate handling strength (no cure time, faster through-put and delivery)
- Simplified process – no mixing or curing of liquid adhesives in the factory
- No tooling of structural sealant
- Reduced process variables/less risk
- Less waste
- No silicone testing is needed
- Cost reduction on the inspection and maintenance of the 2 component mixer

Challenges and disadvantages:

- Tolerances are smaller because of the absence of sealant
- The appliance of pressure on the bond, which is a practical challenge (production)
- Replacement issue is not solved with this detail

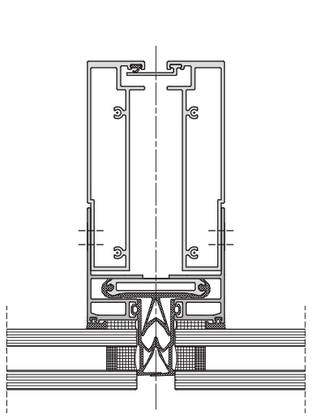
Conclusion

Variant evaluation



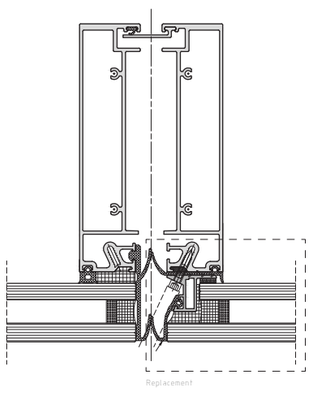
Variant 1.1 - Slider profile

Factory-bonded replacement:	X	-
Traceability:	V	By the use of the small slider profile, everything can be fixated on the same batch
Process improvement:	+/-	Only the extra application of the small slider profile
Cost:	+/-	Only the small slider profile: extra material
Additional comment:		Very good option, except for the replacement issue



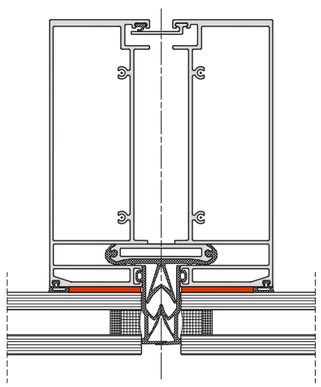
Variant 1.2 - Partial framing

Factory-bonded replacement:	V	Possible with the partial framing. Project specific problems with this detail might occur. (Aesthetic/practical)
Traceability:	V	Smaller profile ensures less batches. Yet, this profile might not be small enough for mass processing
Process improvement:	-	Extra labour because of the partial frame
Cost:	-	Cost will be higher because of the partial frame, extra material and labour
Additional comment:		Not a very good option, but is a variant that improves both on factory bonded replacement and the tracing.



Variant 1.1 - Quaternario profile

Factory-bonded replacement:	V	A very good option for replacement. Initially this variant does not bring extra cost.
Traceability:	X	-
Process improvement:	+/-	Process stays the same. Only for replacement this changes. Not per se an improvement in the process of replacement.
Cost:	+/-	Initially this variant does not bring extra cost.
Additional comment:		

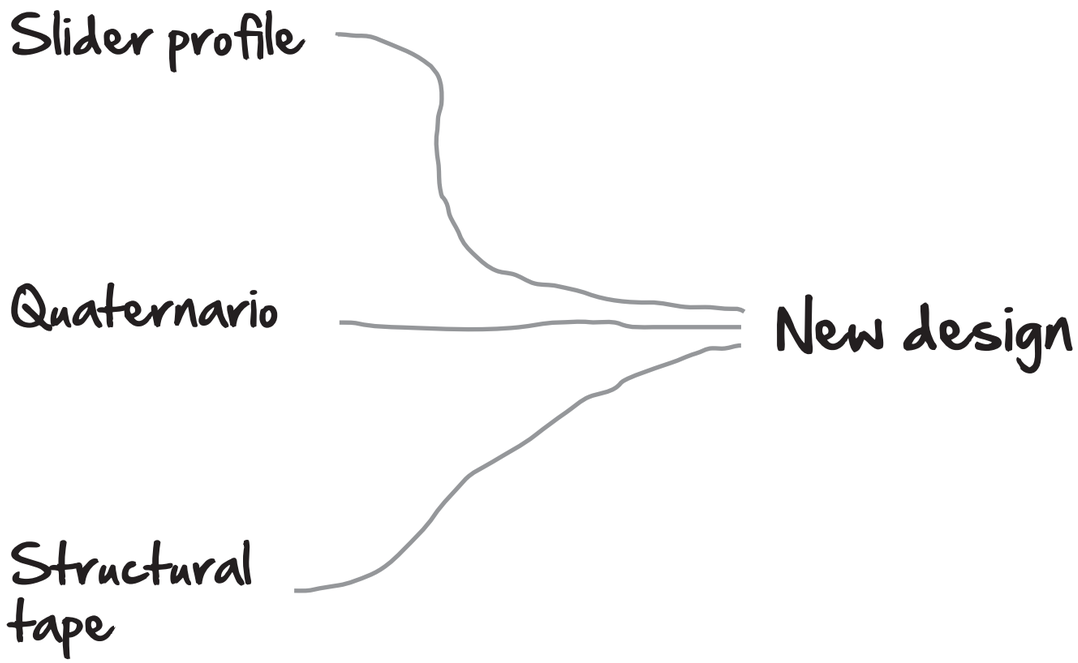


Variant 2.1 - VHB Tape

Factory-bonded replacement:	X	-
Traceability:	X	-
Process improvement:	+	Multiple improvements in the process. Less risk, easier appliance, no toolint, less waste, etc.
Cost:	+	Less expensive material, less waste and faster processing results in lower cost. Needs to be calculated for exact sum.
Additional comment:		Text

Input

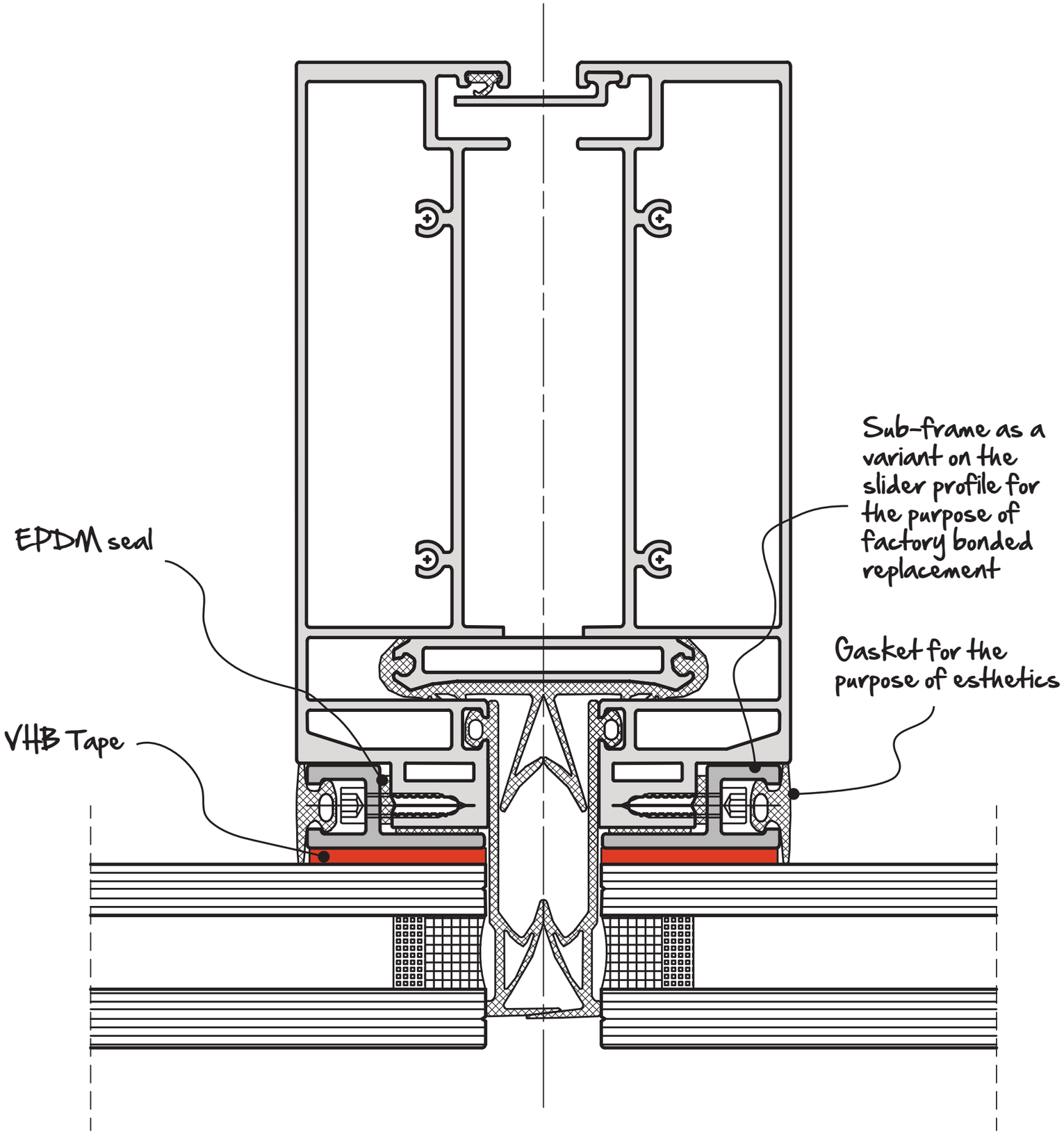
Variant evaluation and conclusion



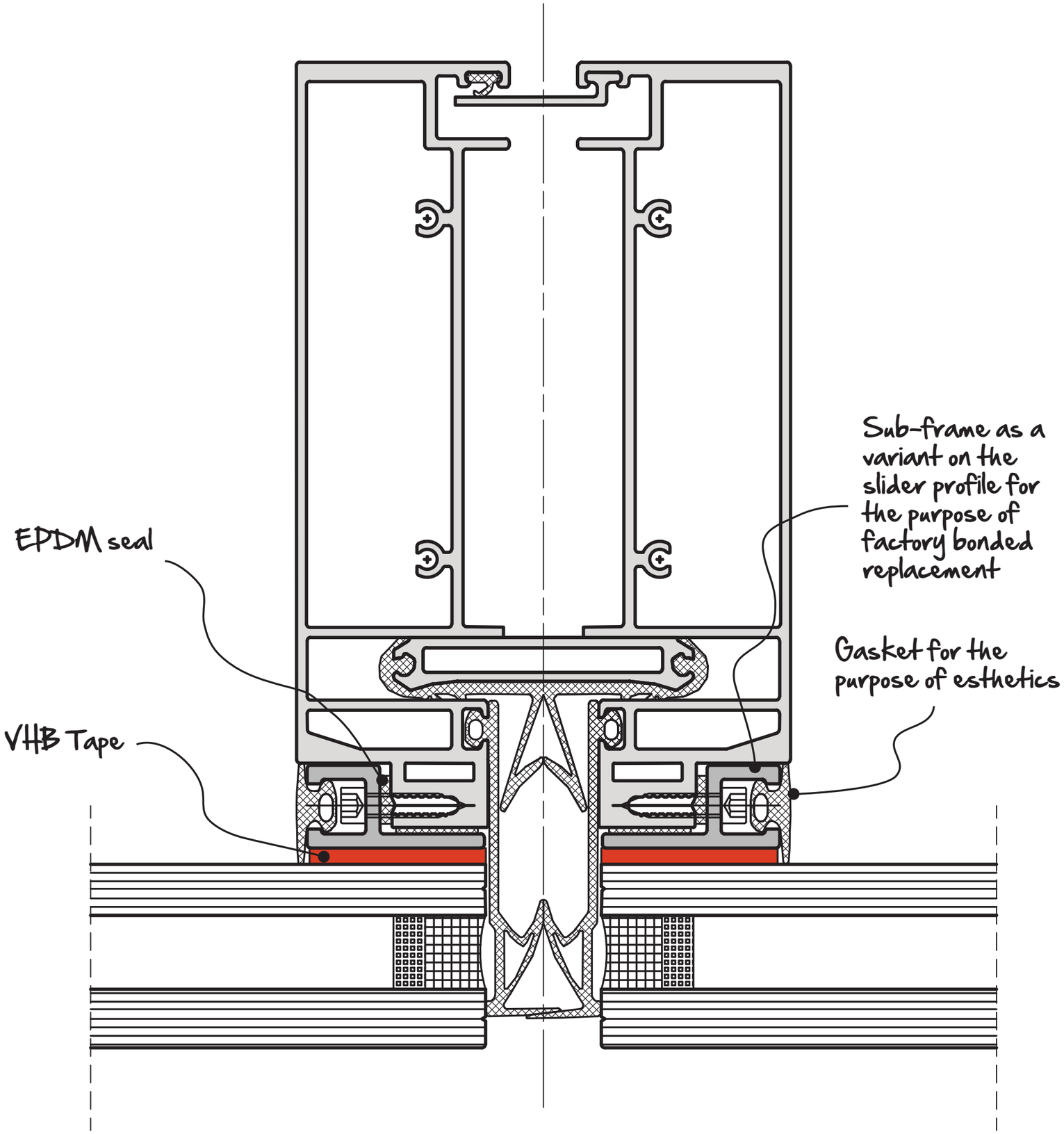
Input:

- Aesthetically correct
- Simple and cheap
- Small tracing profile
- Combination of tracing with replacement
- Combination with tape for multiple purposes

How can the detailing of such an improvement be



Combination of a small, easy to install tracer profile with the option of factory bonded replacement in a sub frame.



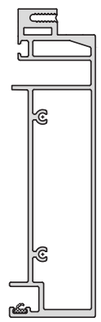
Combination of a small, easy to install tracer profile with the option of factory bonded replacement in a sub frame.

The use of tape for multiple purposes. In the design the thinner tapes gives the option of conceiled fixation.

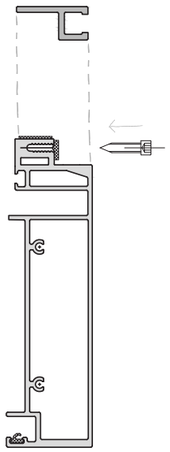
Sikasil + gasket

Tape

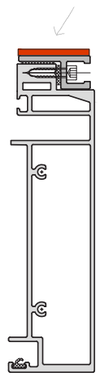
Production



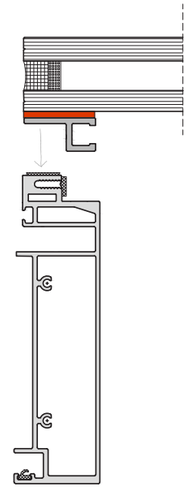
[1] Element frame is assembled in production.



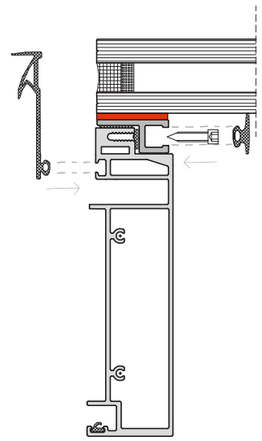
[2] EPDM seal is applied and sub-frame is installed by using some screws.



[3] Tape is applied to the frame.

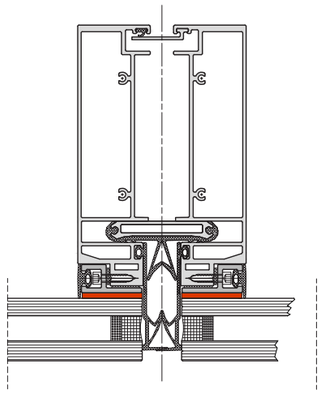


[4] Glass is accurately placed and presure is applied.

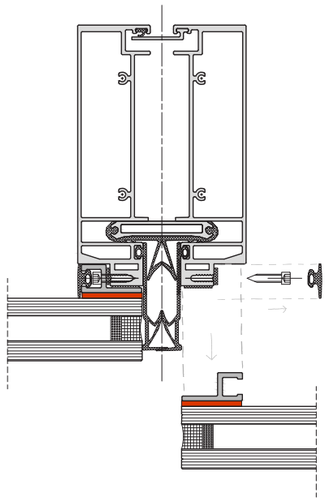


[5] Installation of the gaskets.

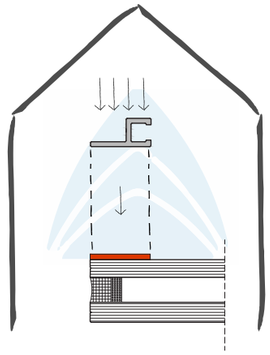
Replacement



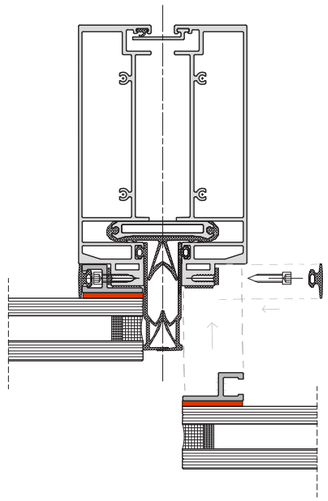
[1] Facade with a damaged glass pane.



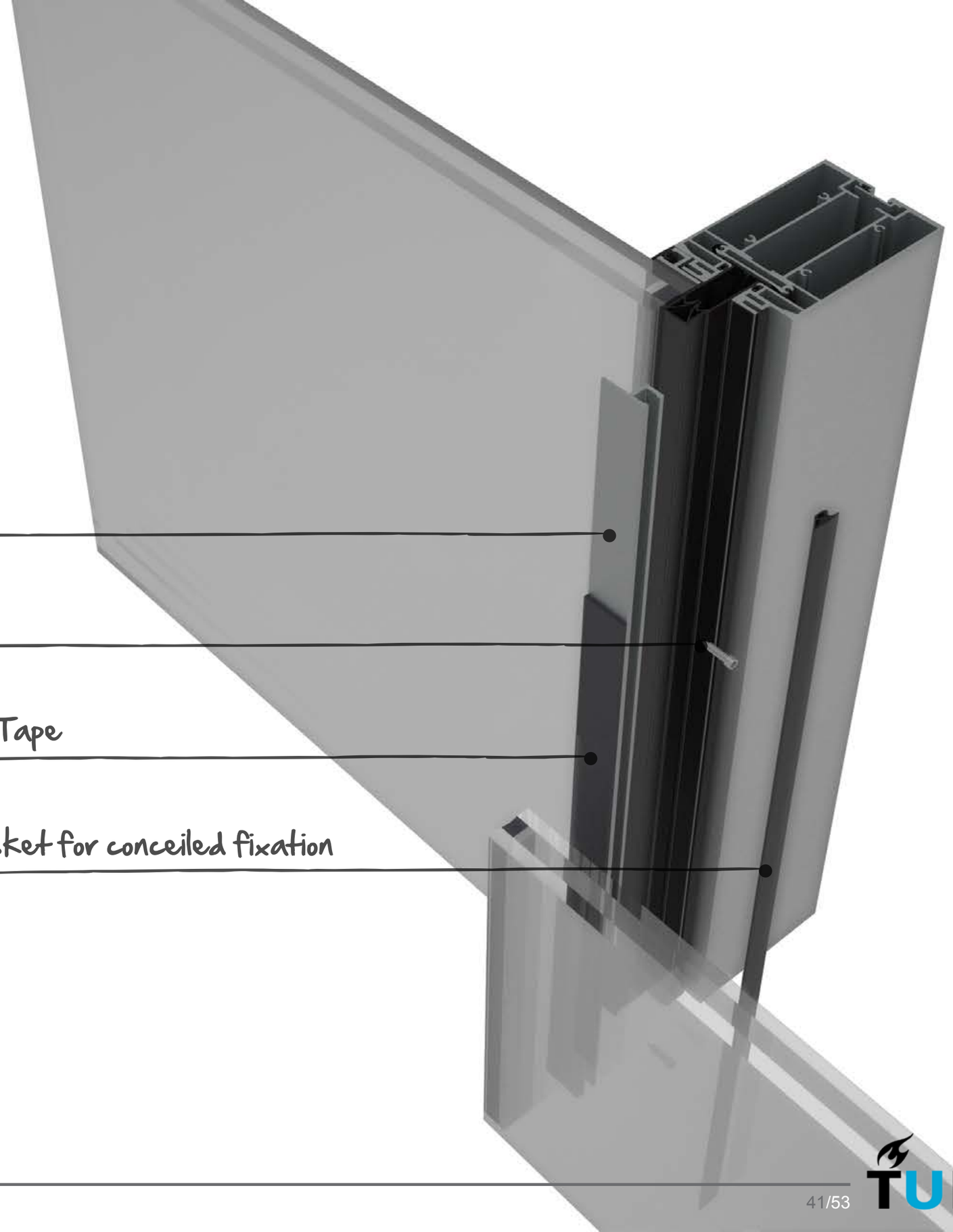
[2] Damaged glass pane is easily removed by loosening the screws on the inside.



[3] A new glass pane is factory bonded to a new subframe.



[4] On site installation of the new element by placing and fastening the screws.


Sub-frame
Sub frame fixation
3M™ VHB™ Tape
Gasket for conceiled fixation

Evaluation

Evaluation

Factors of influence

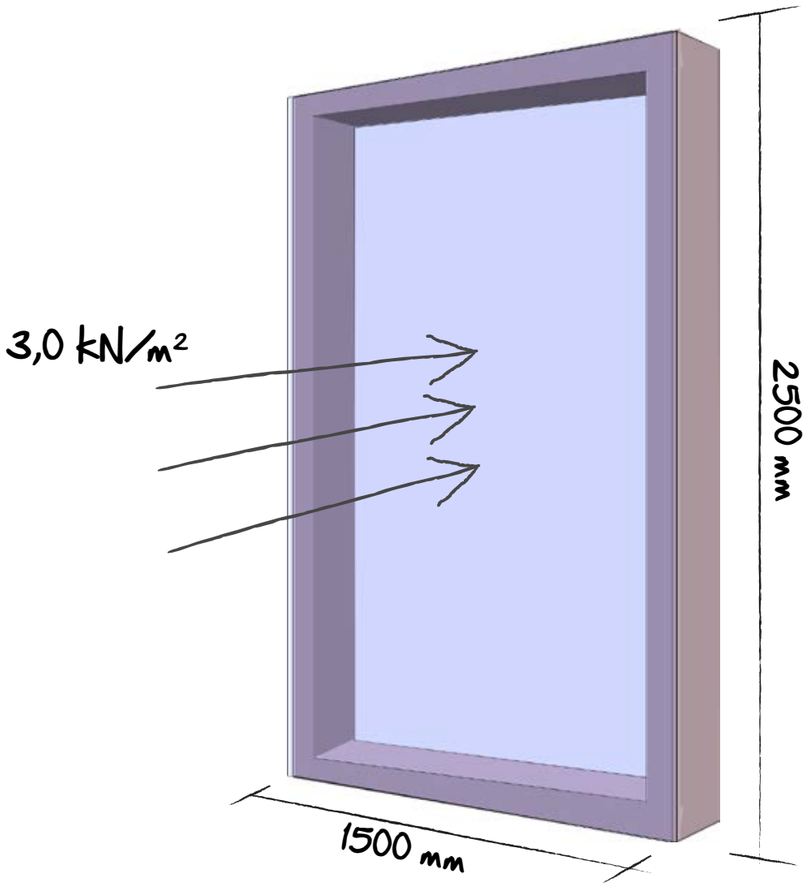
- Aesthetics
- Performance
- Production
- Waste / sustainability
- Costs (labour and material)
- Quality assurance
- Process flow
- Warranty

What reasons are there to change, or to not change, the current process? In other words: What benefits are needed to make a proposed improvement feasible?

Evaluation

Aesthetics

Joint calculation →



Sikasil SG-500 2-part silicone sealant

σ_{dyn} : 140 kPa

Bite: 17 mm + 10 mm
Thickness: 6 mm

3M™ VHB™ Tape

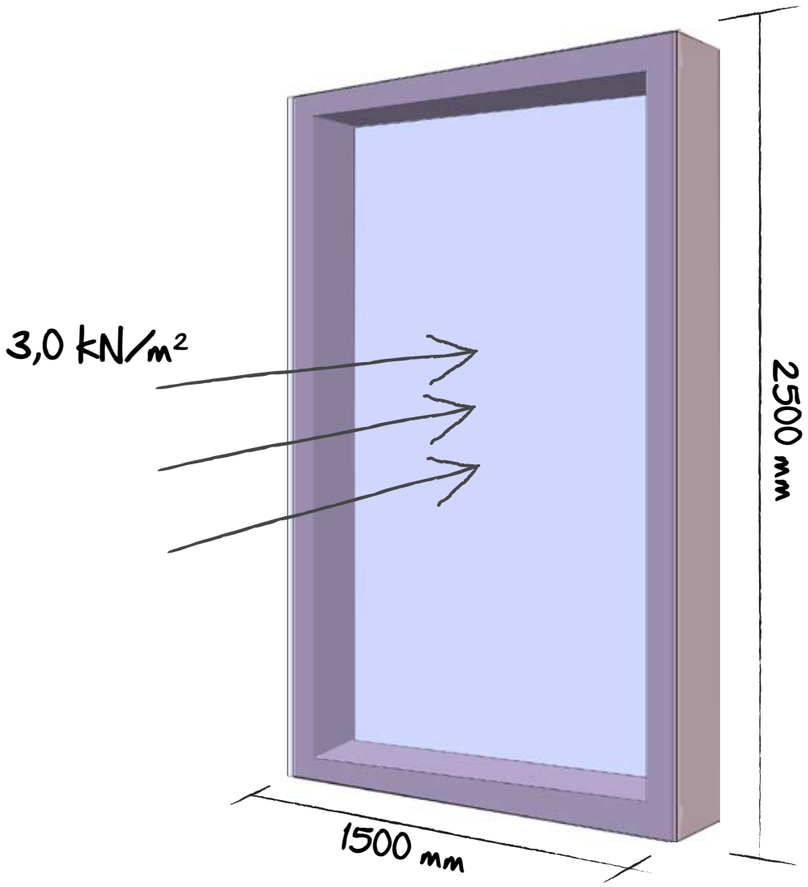
σ_{dyn} : 85 kPa (60% of silicone sealant)

Bite: 30 mm
Thickness: 2,3 mm

Evaluation

Aesthetics

Joint calculation →



Sikasil SG-500 2-part silicone sealant

σ_{dyn} : 140 kPa

Bite: 17 mm + 10 mm
Thickness: 6 mm

3M™ VHB™ Tape

σ_{dyn} : 85 kPa (60% of silicone sealant)

Bite: 30 mm
Thickness: 2,3 mm

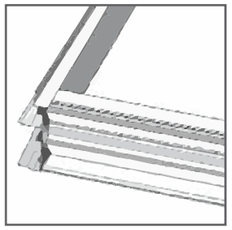
Advantages:

- No colour mismatch as with gasket and sealant
- Possibility for conceiled fixation

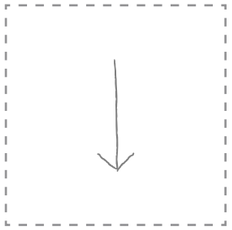
Evaluation

Production

Sikasil SG-500
2-part silicone sealant



Frame assembly.

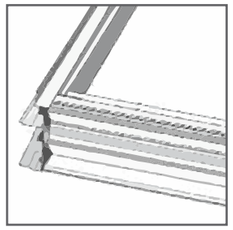


Surface preparation.

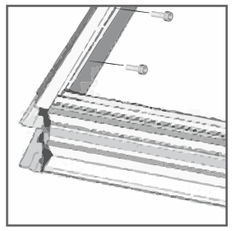
Production tests for the quality assurance of 2-part silicone sealant.

Placement of glass on frame.

New design with
3M™ VHB™ Tape



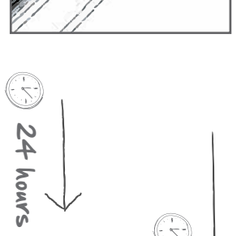
Frame assembly.



Installation of sub-frame.

Surface preparation.

Tape application.



Frame assembly.

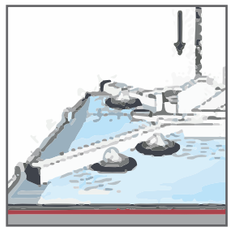
Tooling. Applying gentle pressure to assure maximum contact and remove of excessive sealant.

24 hours

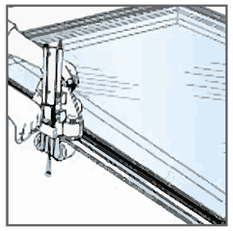
Storage

72 hours

Installation



Joining of parts. Spacers are used for glass allignment.



Appliance of pressure. At least 1 kg/cm². This can also be achieved with a vacuum table.

Immediate handling strength. Storage is directly possible.

24 hours

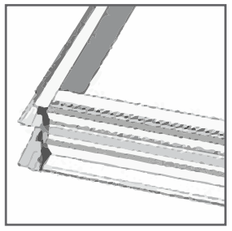
Storage

Installation

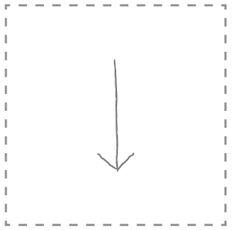
Evaluation

Production

Sikasil SG-500
2-part silicone sealant



Frame assembly.

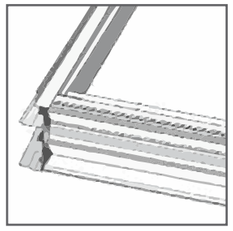


Surface preparation.

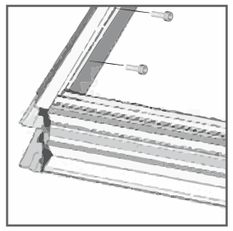
Production tests for the quality assurance of 2-part silicone sealant.

Placement of glass on frame.

New design with
3M™ VHB™ Tape

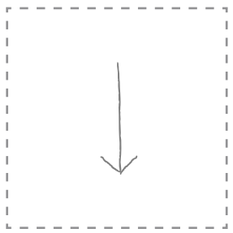


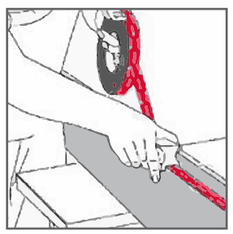
Frame assembly.



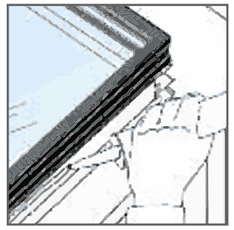
Installation of sub-frame.

Surface preparation.

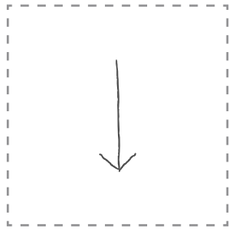


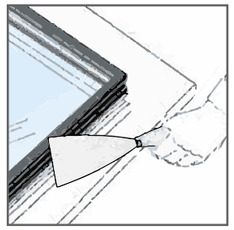


Tape application.



Frame assembly.

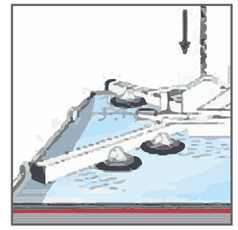




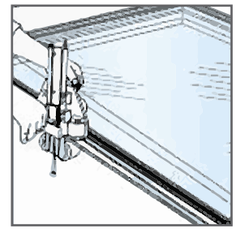
Tooling. Applying gentle pressure to assure maximum contact and remove of excessive sealant.

Improvements:

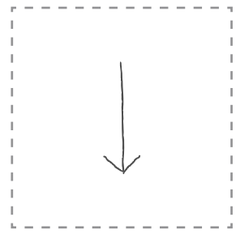
- No mixer open time and dependence on the mixer
- No production tests
- Easier appliance
- Immediate handling strength



Joining of parts. Spacers are used for glass allignment.



Appliance of pressure. At least 1 kg/cm^2. This can also be achieved with a vacuum table.



Immediate handling strength. Storage is directly possible.

Downsides:

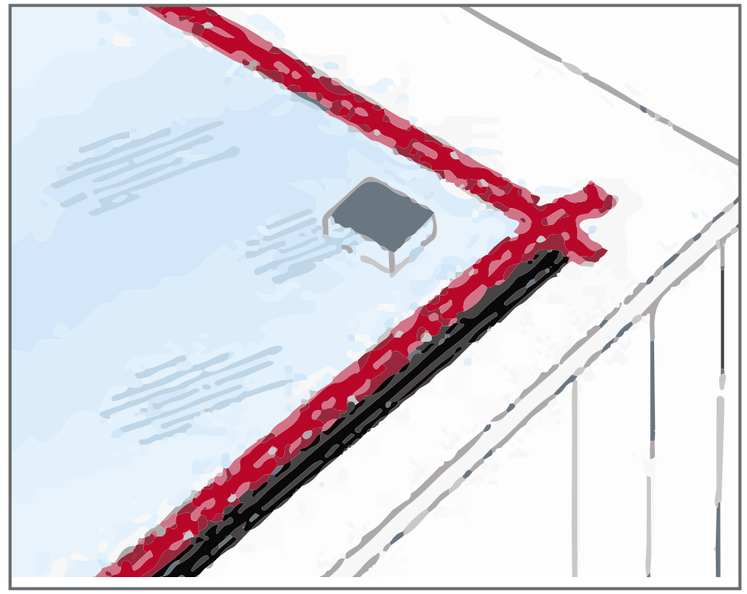
- Extra step in installation of the sub frame
- Investment (time and money)
- Tolerances
- Glass alignment
- Pressure appliance

Waste / sustainability

Yet to be conducted:

Measurement of the amount of sealant waste

Flushing of the mixer / pump and the sealant before tooling illustrate waste.



Tape, before and after finishing. Only the overlap is wasted (<5%).

Evaluation

Costs

Needed input:

- Actual costs of the product
- Amount of sealant waste
- Extra cost of subframe

	SG-500	3M™ VHB™ Tape
Cost of Manpower per panel		
sealing 9min/lm at 43,- p/h	6,50	4,88
Cost of products		
Backing gasket	0,90	0,00
Silicone/Tape	1,50	3,25
Total per lm	**8,90**	**8,13**

Cost of manpower: *43 €/h*
Sealing: *9 min/m*
Tape application: *6,8 min/m*

Prices Silicone: *€5.10 /liter*
Prices VHB: *€3.25 /meter*

Evaluation

Quality assurance / process flow

Exclusion of steps in process:

- Unitisation (no material specific tests)
- No production tests (tape has consistent properties)
- No tracing of the profiles (one batch)

+ Possibility for factory bonded replacement

	Sikasil SG-500	Performed by
Design Phase		
Step 1	Project manager (customer) or responsible Sika persons send all relevant design details (drawings - including bonding situation) and project details (wind loads, max. temperatures, glass/panel sizes) to Sika (ch-fcc@ch.sika.com or Fax +41 58 436 5407) for inspection	**Customer**
Step 2	Sika - checks joint details - checks joint dimensions - assesses the materials used - recommends the correct sealant for these applications based on all the details known	**Sika**
Test Phase		
Step 3	Project manager sends all substrates and ancillary materials to Sika for testing. The number and sizes of the samples are described in the leaflet "Project Submittal Information"	**Customer**
Step 4	Sika conducts the following tests: - Adhesion tests to all substrates (glass, facade panels and frame materials) - Testing compatibility with all materials that our adhesives and sealants come into contact with - Based on the results, Sika makes recommendations for cleaning and, if necessary, priming the surfaces. The results and recommendations are summarized in a laboratory report. A guarantee can only be given if all submitted samples are compatible and the adhesion is sufficient	**Sika**
Application Phase		
Step 5	Sika instructs the applicator on all matters of the applications: - Adhesive application - Quality control during application - Help with machine application Sika also helps with the correct application of its products (e.g. weathe-rsea-ling) on site. After successful instruction, the customer receives a training certificate from Sika	**Sika**
Step 6	The customer applies the Sika products as instructed and diligently carries out the recommended quality controls during processing. The quality control is documented on the appropriate Sika forms. If desired and agreed, the customer sends the test specimens to Sika. Mechanical properties are measured in one of the FFI Competence Centers	**Customer**
Warranty Phase		
Step 7	Once application of the products is complete, the customer sends all documents to Sika for inspection	**Customer**
Step 8	Based on the umbrella contract, Sika provides an extended warranty on the sealant, where consequential damage by failure of the sealant is included	**Sika**

Evaluation

Warranty

Now:

- Permasteelisa Umbrella contact with Sika
- Bulk discount
- Extended warranty (consequential damage is included)

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With the implementation of this concept:

- New agreements are needed
- Similar procedure as with Sika, but with less steps.
- Limited warranty (only the tape can be refunded)

→ Research in collaboration with 3M (discussion and case studies)

Conclusion

Conclusion

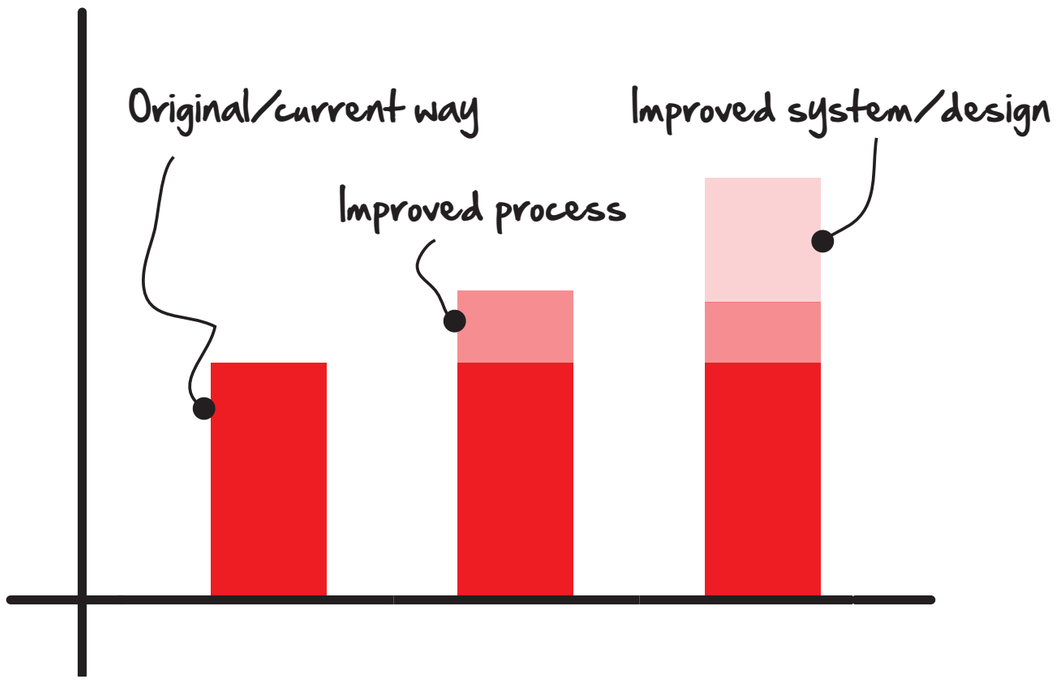
General conclusions

- *How and to what extend can the process be improved, merely on process level?*

- *What reasons are there to change, or to not change, the current process? In other words: What benefits are needed to make a proposed improvement feasible?*

- *How and to what extend can the process be improved by implementing a new system and what should these improvements be?*

- *How can the detailing of such an improvement be?*



Conclusion

Conclusions on the final design

Significant improvement in:

- *Process flow*
- *Traceability issue*
- *Production*
- *Replacement*
- *Cost?*
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- *Warranty*

This is not exclusively the only design that could improve the process, but it is engineered on principles that should be used for improvement by design.

(Exclusion of risk factors, combining design measures for different causes, etc.)

Conclusion

Further pursuits

3M collaboration:

- Warranty question -> Case study
- Sample testing
- Detail and process evaluation

At Scheldebouw:

- Measuring the amount of sealant waste
- Cost calculation elaboration

Thank you