RESEARCH REPORT

Circularity in Referentiedetails

ISSO Referentiedetails as a tool for insight into disassembly possibilities for future reuse

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1 INTRODUCTION

1.1 MOTIVATION

In a European context, it has been decided that the European economy must be fully circular by 2050. For construction, this means that building materials from buildings must be able to be used entirely as raw materials by reuse or by converting them into a new raw material. The central government aims to halve the use of primary raw materials by 2030 compared to 1990.

To this end, ISSO has investigated the possibilities for providing insight into the suitability for future reuse in the ISSO Referentiedetails, an already existing and broadly functioning instrument for construction in the Netherlands, in which performance layers have recently been included that show the performance of the considered connections for other (building physics) aspects.

The presented ISSO report is the result of this research. It reflects the state of art in the field of technology and research, without laying down normative design or implementation methods.

1.2 OBJECTIVE

In February 2020, the European Commission of Internal Market, Industry, Entrepreneurship and SMEs formulated the objective for the construction sector in the report *Circular economy principles for building design* [1] to help reduce the environmental impact and life cycle costs of buildings.

The method described in this report for providing insight into an important precondition for suitability for future reuse (disassembly possibilities) in the ISSO Referentiedetails contributes to the objectives in the area of dismantling possibilities mentioned in the report Circular economy principles for building design:

- Increasing knowledge about building techniques to facilitate disassembly and improve the durability and adaptability of a building (H2 E).
- Sharing information to increase the productivity of buildings with better design and performance of construction products (H2F).
- Facilitate the design of products and systems so that they can be easily reused, repaired, recycled or recovered (H2 H).

To this end, the possibilities for providing insight into the suitability for future reuse in the ISSO Referentiedetails to contribute to these objectives have been investigated. More insight in this area contributes to the transition to a circular economy.

De combinatie van de nieuwe prestatielayers voor losmaakbaarheid met de eerder toegevoegde presatielayers voor andere bouwfysische aspecten helpen de consequenties van losmaakbare verbindingen te zien op andere bouwfysische prestatie eisen (zoals luchtdichtheid, thermische isolatie, akoestiek, brandveiligheid).
Het voorliggende rapport is het resultaat van dit onderzoek en vormt een startpunt van de voorgestelde methode om voor te leggen aan de stakeholders in de bouw voor verdere ontwikkeling en aansluiting op andere methoden voor circulariteit.

1.3 TARGET GROUP(S)

- Contractors;
- Architectural designers/draughtsmen;
- Manufacturers of building products;
- Engineering companies;
- Teachers and students in architecture.

The Dutch Association of Polyurethane Rigid Foam Manufacturers (NVPU) is involved in this project as co-initiator. Polyurethane (PUR) and Polyisocyanurate (PIR) rigid foam are used as materials for thermal insulation in construction. From an environmental point of view, it is preferable to immediately reuse existing hard foam insulation products that are released from a building to be demolished. Because the thermal performance of hard foam hardly decreases over time and the potential lifespan of the material far exceeds the building life, reusing polyurethane rigid foam insulation seems to be a serious option in the context of circular construction. NVPU has therefore contributed financially and substantively to the creation of this ISSO report.

1.4 SCOPE

1.4.1 Focus

The ISSO Referentiedetails provide insight into the connection between different construction products, elements and components for different types of structural connections (details). Drawings of architectural connections are primarily focused on the structural connections between the various parts that are connected to each other on the construction site. The connections of materials and components within a (composite) construction product, such as a prefabricated building element, is not part of consideration. This is because, for the purpose of being able to directly reuse a (composite) construction product, such as a prefabricated building element, the detachability within the (composite) construction product is not relevant. Moreover, the building regulations do not apply to this, but the European Construction Products Regulation (CPR 305/2011).This means that the performance of this at product level must be recorded in a Declaration of Performance (DoP) with the CE marking, or in a quality declaration in which the performance for the life cycle assessment (LCA) is recorded or the environmental performance (NMD). In the LCA, the potential for reuse is expressed, for example by the % of the product that can be reused and the part that is damaged and can only be recycled.

1.4.2 Opportunities

Precisely because the ISSO Referentiedetails show connections between different, whether or not pre-assembled, construction products, these are extremely suitable for assessing the way of joining these products on how easy they are to detach (detachability) in order to be able to reuse the products

again. The assembly method, with the possibility of the type of connection and its accessibility at the time of disassembly, determine to a large extent the damage caused to the construction products by disassembly and thus the (decrease in) potential for reuse of the products. The detachability of the products in the details is therefore an important condition for reuse and thus for the circularity of the (whether or not pre-assembled) construction products in the processing method considered.
Providing insight into the consequences of the types of connections and their accessibility at the time of disassembly determines the detachability within a detail. This insight facilitates:

- designers to make the right choices for architectural detailing;
- innovation of fastening methods by clarifying where the problems arise;
- the assessment of building(s) in the field of Environmental Performance (e.g.MPG and LCAs) by providing information (e.g. in the future via BIM).
- the assessment of the interaction between detachability and other building physics aspects.

2 DEVELOPMENT OF PERFORMANCE LAYERS 'DETACHABILITY'

2.1 INSTRUMENTS

The European Commission's report [1] mentions a number of means of achieving the objectives. ISSO has taken up the following points to work out.

- Establishing a number of relevant indicators related to the overall circular management system in a building.
- Using existing environmental product declarations.
- Enabling designers to explore possibilities for the use of products and materials already available in existing buildings.
- Proposing different solutions for circularity and providing information for cost calculation.
- Facilitating the maintenance and repair of various parts of buildings, construction products and systems.
- Facilitating assessment of the sustainability of different parts of buildings, building products and systems.
- Connect to developed tools (e.g. BIM, material passports of construction products and systems) to enable fast and accurate assessments of recovery, reuse and recycling potential of specific products and systems and associated value propositions.

ISSO has chosen to use and further develop an already existing and broadly functioning instrument for construction details in the Netherlands, the ISSO Referentiedetails (previously SBR Referentiedetails), to make this possible. Within this project, new performance layers for future reuse have been developed using the recently developed determination methodology of Alba Concepts (Building Circularity Index). The detachability of architectural connections has, on the basis of this determination method, been made visually clear for different scenarios.

2.2 DETERMINATION METHOD

As a base for the determination method for detachability in the ISSO Referentiedetails, the measurement method developed by Alba Concepts together with DGBC and W/E advisors commissioned by the Ministry of the Interior and the Circular Construction Economy Transition Agenda was used: 'Çircular Buildings, measurement method detachability'. [2] This measurement method is based on four factors: connection type (TV), accessibility of the connection (ToV), integration (DK), and edge confinement (RA). To each element a value of 0.1 - 1.0 can be assigned for each of these aspects, with 0.1 giving the lowest rating for detachability and 1.0 the highest. The first two indices determine the detachability index of the connection (LIc), Formula 1) and the last two the detachability index of the composition (LIs, see Formula 2). These two detachability indices together determine the detachability of the product (LIp, Formula 3 According to this method, as part of circular construction, the detachability is included in BREEAM-NL and GPR-Building.

Formula 1: Detachability index of the connection, taken from 'Circular Buildings' [2]

$$LIc_n = \frac{2}{\frac{1}{TV_n} + \frac{1}{ToV_n}}$$

containing:
LIc_n detachability index of the connection of product or element *n*:
TV_n type of connection of product or element *n*
ToV_n accessibility of the connection of product or element *n*

Formula 2: Detachability index of the composition, taken from 'Circular Buildings' [2]

$$LIs_n = \frac{2}{\frac{1}{DK_n} + \frac{1}{RO_n}}$$

containing:
LIs_n detachability index of composition of product or element *n*:
DK_n Integration of product or element *n*
RO_n edge confinement of product or element *n*

Formula 3: Detachability index of the composition, taken from 'Circular Buildings' [2]

$$LIp_n = \frac{2}{\frac{1}{LIc_n} + \frac{1}{LIs_n}}$$

containing:
LIp_n detachability index of the product or element *n*:
LIc_n detachability index of the connection of product or element *n*:
LIs_n detachability index of composition of product or element *n*:

*Table 2 1: Assessmentof the type **of connection**,taken from 'Çircular Buildings' [2]*

Connection type		Score
Dry connection	Loose (no connection material) Click Velcro Magnetic	1,00
Connection to added elements*	Bolt and nut Spring Corner joints Screw Connections with added connection elements**	0,80
Direct integral connection	Pin*** Nail	0,60
Soft chemical bond	Kit connection Foam compound (PUR)	0,20
Hard chemical bond	Adhesive Deposit connection Weld Cement bond Chemical anchors Hard chemical bond	0,10

* Added connecting elements must be made of materials that are insensitive to degradation due to weather and/or use conditions (e.g. stainless steel).

** For example, a façade hanging system

*** For example, a staple-connection

*Table 2 2: **Assessment of** the **accessability** of **the connection**, taken from 'Çircular Buildings' [2]*

Accessibility of the connection (ToV)	Score
Freely accessible without extra actions	1,00
Accessible with additional actions that do not cause damage	0,80
Accessible with additional operations with fully repairable damage	0,60
Accessible with additional operations with partially repairable damage	0,40
Inaccessible – irreparable damage to the product or surrounding products	0,10

*Table 2 3: **Assessment of integration**, taken from'Çircular Buildings' [2]*

Integration (DK)	Score
No integration - modular zoning of products or elements from different layers.	1,00
Occasional integration of products or elements from different layers.	0,40
Full integration of products or elements from different layers.	0,10

*Table 2 4: **Assessment** of **edge confinement**, taken from'Çircular Buildings' [2]*

Edge confinement (RO)	Score
Open, no obstacle to the (interim) removal of products or elements.	1,00
Overlap, partial impediment to the (interim) removal of products or elements.	0,40
Closed, complete impediment to the (interim) removal of products or elements.	0,10

2.3 APPLICATION METHOD WITHIN ISSO-REFERENTIEDETAILS

Because the ISSO Referentiedetails are extremely suitable to show the connections between different elements and products and do not reflect all the information of the elements, the assessment of the detachability in the details is limited to the detachability index of the joints (LIc).

2.3.1 Definitions

In order to maintain clarity between the applied measurement methods for detachability, the same definitions are used for building components as for 'Circular Buildings, measurement method detachability'; [2]

- **Product**: A part that arrives at the construction site and is further processed in a building. This can be, for example, a brick or a prefab (masonry) façade.
- **Element**: A component consisting of several products, which arrive at the construction site as a single pre-assembled whole. For example, an masonry wall on the construction site forms an element with bricks and mortar as products.
- **Sealing material**: A material or product that ensures the seal between different products or elements.
- **Connection material**: A material or product that provides the (constructive) connection between different products or elements.

As with the measurement method of 'Çircular Buildings, measurement method detachability', [2] in the ISSO Referentiedetails the sealing materials and fasteners are *not assessed* for detachability.

In the ISSO Referentiedetails, a product is only assessed for detachability if in the considered scenario (see scenarios) this product is removed from the building individually at the construction site. The processing steps taken after disassembly of the products and elements are not taken into account and assessed when determining the MPG or the LCAs.

2.3.2 Scope

- As with the measurement method of 'Circular Buildings, measurement method detachability' [2], the ISSO Referentiedetails do not assess the sealing materials and connection materials for detachability. This benefits the usability of the method because it avoids unnecessary complexity and in the totality of materials it is only a fraction of the weight and volume. In the future, it may be considered to assess this.
- In the ISSO Referentiedetails, a product is only assessed for detachability if in the scenario under consideration (see scenarios) this product is removed from the building individually on the construction site. The processing steps taken after disassembly of the products and elements are not taken into account and assessed when determining the MPG or the LCAs.
- Because it is a simplified method, the damage caused to the considered element by removing a previous element is not taken into account in the assessment of the detachability of the element in question.
- The accessibility of the connection refers to 'extra actions' to remove the element. No statement is made about the time and labor that this costs as there is insufficient information

available about this. This can be a valuable addition in a follow-up project because it has a direct impact on the feasibility of disassembly.
- The presented method is designed to assess common ways of assembly and disassembly. Innovative mounting and disassembly can therefore be assessed worse than is actually the case (for example; glue that comes off after heating or wetting without causing damage to the elements).

2.3.3 Scenarios

Products can be disassembled to extend the life of the building through maintenance or transformation or to extend the life of products or materials by reuse beyond the life of a building or component.

The building is a complex system with elements that have different timescales of change. In his book 'How Buildings Learn: What Happens After They're Built' [3], Steward Brand identifies the 6 'shearing layers of change' based on a concept previously developed by the architect Frank Duffy;

•Site	geographical location;
•Structure	foundation and load-bearing elements;
•Skin	outer surfaces that separate the outside from the inside;
•Services	e.g. wiring, plumbing, sprinkler systems, HVAC, lifts;
•Space Plan	interior organization (walls, ceilings, floors and doors);
•Stuff	parts that are not attached to the building (e.g. furniture, appliances,..)

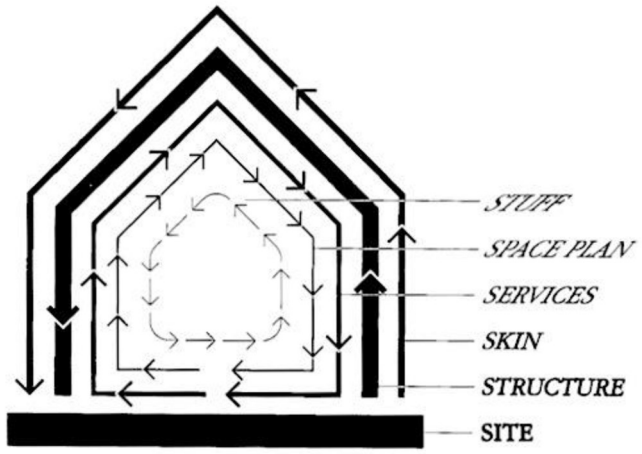

Figure2. 1: The Layers of Brand (Bron [3])

Based on the differences in the lifespan of the elements, all kinds of scenarios can be defined for which the detachability of products is desired;

- **End-of-life**: The building is dismantled (demolished) at the end of the life of the building.
- **Renovation**: The building is (partially) repurposed or renovated and several elements and products are replaced. This can range from relatively small adjustments such as the re-

insulation of a roof or the replacement of (some) windows through deeprenovation in which all facades, floors and roofs are tackled.
- **Maintenance**: The element or product is removed from the building because it needs to be replaced because of, for example, defect, decreasing performance or increased or changed requirements.

Between the two extreme scenarios End-of-life and Maintenance and management there are many degrees of renovation. In order to develop the method, only the two extreme scenarios have been worked out in this project.

2.3.4 End-of-life

For the end-of-life scenario, it is assumed that the elements are removed in reverse assembly order; the reverse construction order. This means that, when the detachability of an element is considered, the previous elements have already been removed and therefore no longer affect the accessibility of the connection. In the ISSO Referentiedetails, all elements are numbered in this reverse construction order. The last element that remains cannot be assessed for detachability because all the connections shown in the relevant detail are no longer present. By default, this is not displayed with a colour in the performance layer.

2.3.5 Maintenance:

For the scenario of maintenance, it has been assumed that all elements that may be eligible for replacement must be removed individually and that all other elements in the structural connection are still present. In particular, this can have a major impact on the accessibility of the connection and can therefore also lead to a lower detachability index for maintenance than for end-of-life: there will be more damage to the element to be detached, but also to the remaining elements. All damage as a result of this must then be repaired.

2.4 VISUALIZATION

Of all the elements that are connected to each other on site, a calculation has been made in the background according to the indicated method. This calculation can be shown in pdf as background information for the details. In the ISSO Referentiedetail, the considered elements are indicated by successive numbering of the disassembly order, a qualitative assessment of the detachability index for the connection per element and the connections themselves. A general legend is shown in Figure 2.2.

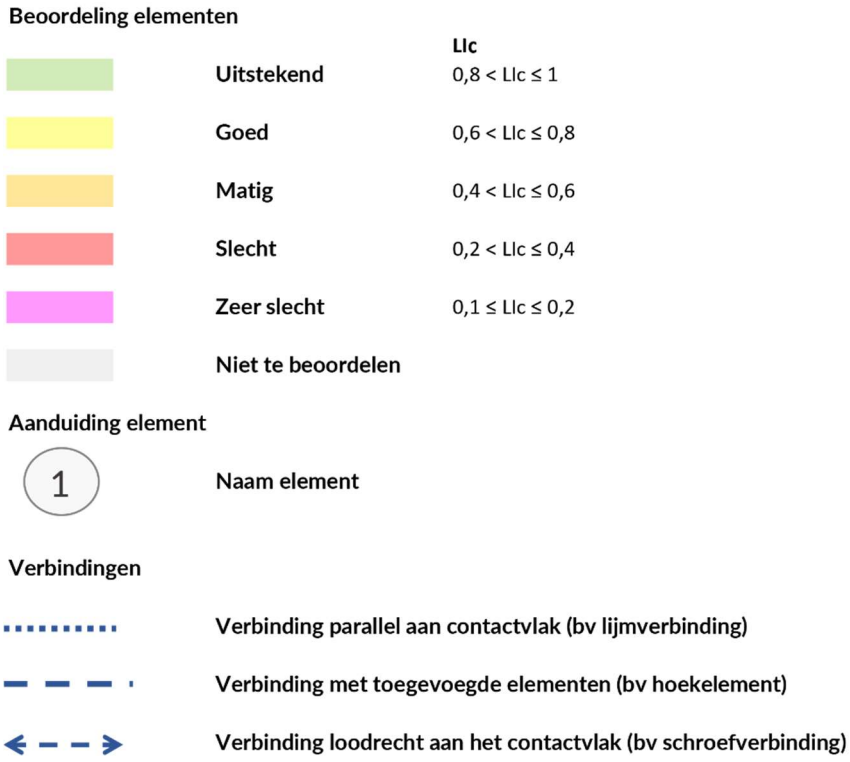

Figure 2.2: General legend for the assessment of the detachability of the joints in the Standard Referentiedetails

2.4.1 End-of-life example

An example of a detail showing the detachability for the end-of-life scenario is shown in Figure Figure 2.3 The additional information shown in the downloaded PDF is shown in Figure 2.4.

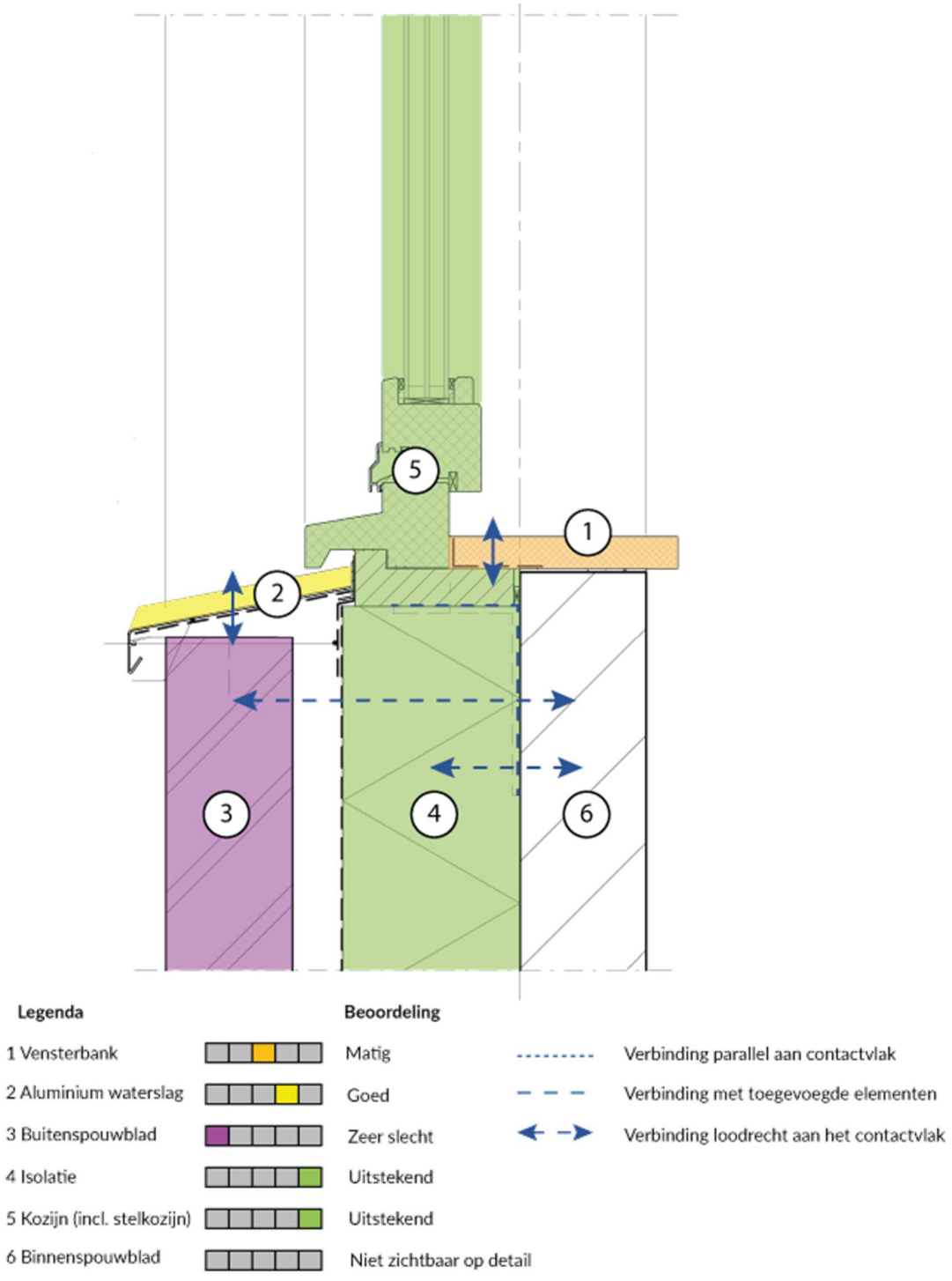

Figure 2.3: Example detail with performance layer detachability for the end-of-life scenario

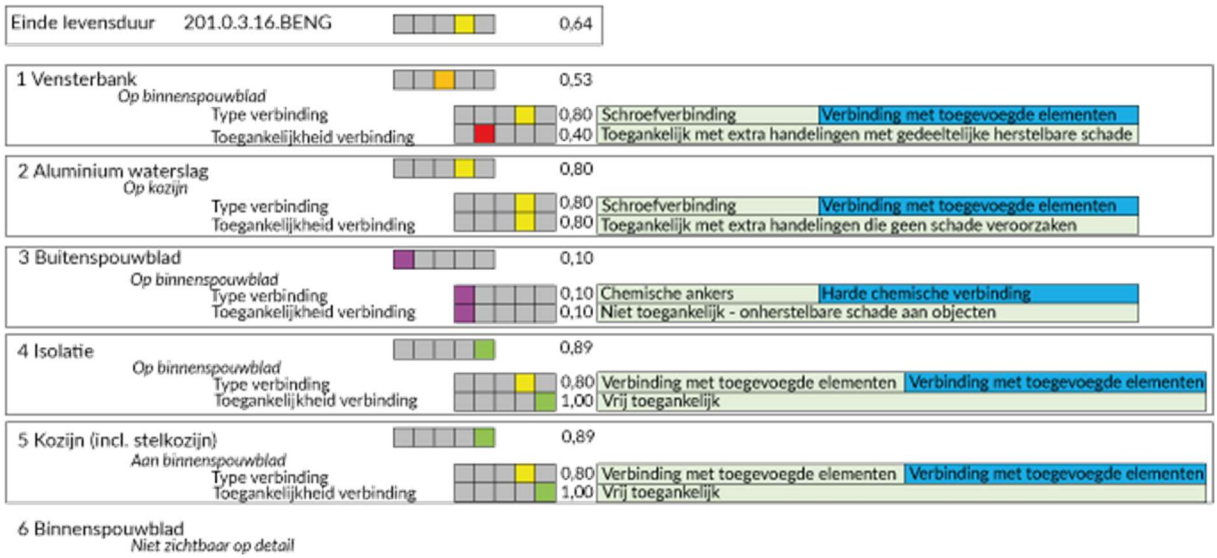

Figure 2.4: details calculation for example detailed end-of-life scenario

In the example detail it becomes clear at a glance where the elements are located that are difficult to detach and therefore where improvement is needed to make the products and elements suitable for reuse. For example, the outer masonry wall has the rating 'very bad' which can immediately be seen in the purple color. In the information in Figure 2.4 the type of connection (chemical anchors) and the poor accessibility of the joint (the masonry will have to be demolished completely to get to the anchors). The connection itself is indicated by the blue arrow.

Note: The information in Figure 2.4 provides a total score of the detail. This number now results from equal weighting of all elements. Some elements will have more influence on the total detachability of the building than others, for example because they occur more often or because the product to be reused has a higher environmental impact. This total score is therefore no more than an indication. The added value of displaying the detachability in the ISSO Referentiedetails lies mainly in the visualization with the colors in the detail itself to see where the problems arise.

Note: Element 3, the outer cavity leaf, is considered as a whole in this scenario. This follows from the definition of the *element* (see § 2.3.1). When removing the outer cavity leaf, this element itself is demolished. In practice, the loose stones can be cleaned and reused. In the MPG, module D, this scenario can be worked out.

2.4.2 Example maintenance

An example of an assessed detail for the maintenance and management scenario as it appears on ISSO Open is given in Figure 2.5. The additional information displayed in the PDF download is shown in Figure 2.6.

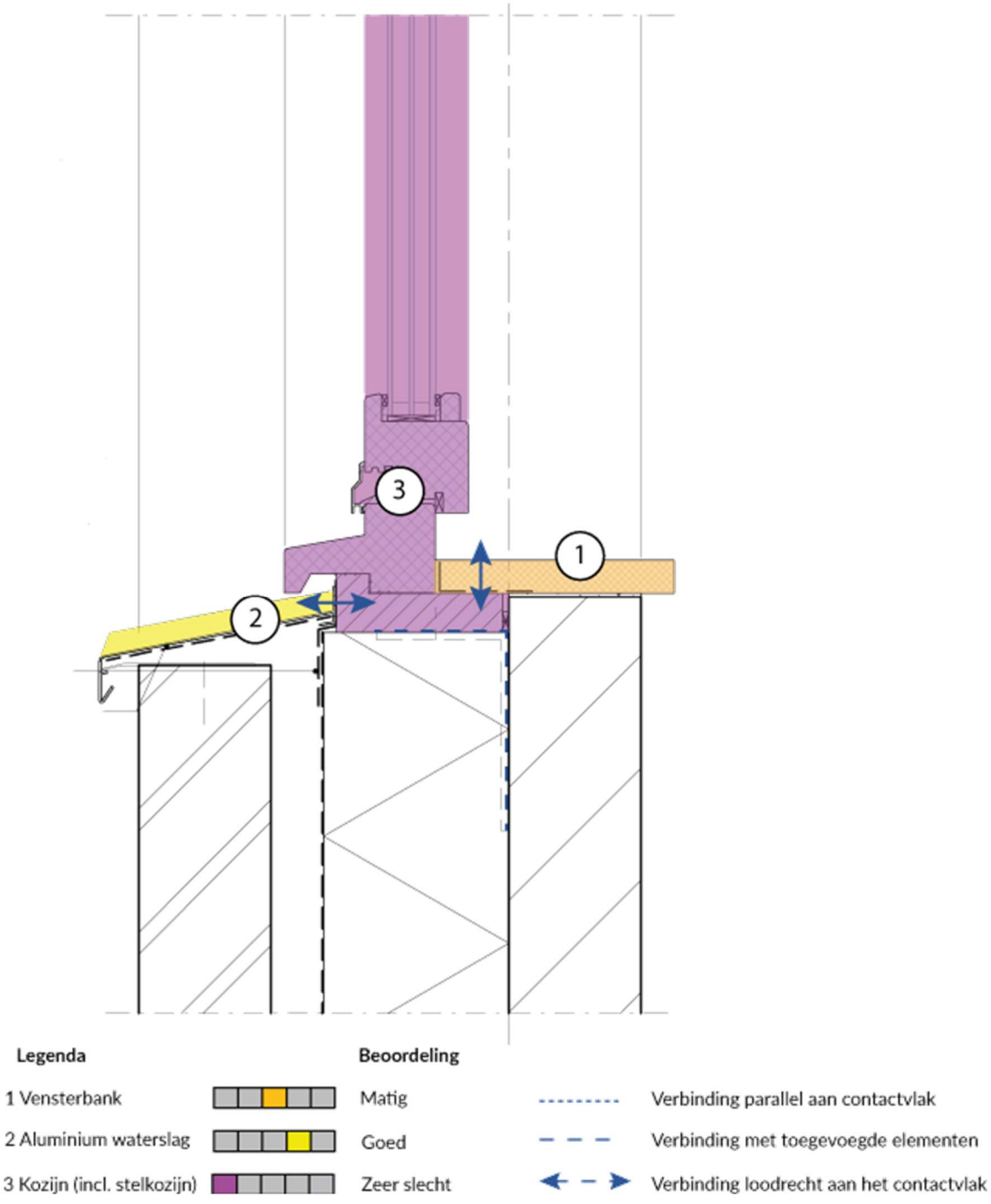

Figure 2. 5: Example detail with performance layer detachability for the maintenance and management scenario

Figure 2. 6: details calculation for exampledetail scenario maintenance and management

When comparing detachability for the end-of-life scenario with the detachability for the maintenance scenario, a number of things stand out;

- In the maintenance scenario, only 3 elements are assessed because it has been assumed that only the windows are eligible for replacement.
- The assessment of detachability of the window in the end-of-life scenario is very good, but in the maintenance and management scenario very poor. In the information in Figure 2.6 it can be seen that the accessibility of the connection is poor because first part of the outer masonry wall must be removed and part of the insulation to get to the corner connection. This causes irreparable damage to these two elements. From this it can be seen that there are different points of attention in the different scenarios for, in particular, the accessibility of the connection.

Note: Figure 2.6 provides a total score of the detail. This number now results from equal weighting of all elements. Some elements will have more influence on the total detachability of the building than others, for example because they occur more often or because the product to be reused has a higher environmental impact. This total score is therefore no more than an indication. The added value of displaying the detachability in the ISSO Referentiedetails lies mainly in the visualization with the colors in the detail itself to see where the problems arise.

Note: Element 3, the frame, is considered as a whole in this scenario. This follows from the definition of the element (see § 2.3.1). In practice, however, it is quite conceivable that the operable part is detached from the frame and that this is also reused separately. When refining the method, these types of scenarios can also be worked out.

2.5 CONNECTION WITH OTHER ASPECTS OF CIRCULARITY

The way in which the preconditions for reuse, through detachability, can be visually represented in the ISSO Referentiedetails in a performance layer can, in the future, contribute to the assessment of whether or not a product in its application is suitable for future reuse. If future reuse were to be taken into account in the LCA method, the ISSO Referentiedetails could provide a structural framework within which future reuse could be feasible. In a future project, in collaboration with the NMD, this could be worked out as follows;

2.5.1 Module D

Since July 2020, the environmental performance assessment method has been extended with Module D; *Additional information outside the life cycle of the structure*. The following aspects are assessed;

- Environmental costs and benefits outside the system boundary of the building;
- Possibilities for reuse, recovery and recycling.

Especially for the possibilities for reuse, recovery and recycling, the detachability is of great importance. Due to damage that occurs during disassembly, products can become less suitable or even unsuitable for reuse.

2.5.2 Quality factor K

In the 'Amendment sheet Determination method Environmental performance constructions' (Amendment 1 dated 1 October 2020), a quality factor K is introduced for planned reuse. With this factor, a transparent valuation of reuse can be provided in the LCA of a new product.

The quality factor K is a measure of the remaining quality of the product (and therefore not of material flows) in relation to the initial product. The quality factor K is expressed in a % between 1 and 100 and can be determined by the producer by;

1. Substantiation of technical quality after first use - or;
2. Expected residual life of the second use - or;
3. Market value of the product for reuse in relation to the market value of the new product.

The detachability of the product has a direct influence on the above provisions, as damage to the product after removal has a negative impact on the technical quality of the product.

2.5.3 Linking NMD and the ISSO Referentiedetails

The way of assembly in the building is of course not (only) a property of the product itself, but of the construction method of the entire building. Therefore, the detachability of the products themselves from an architectural context cannot be determined exclusively in a product card and therefore not the (entire) factor K. However, a conditional factor K can be given that may only be used if certain preconditions are met. Reference can be made to the details to be specially developed for future reuse. This can be done in several ways:

- Direct link with specific ISSO Referentiedetails -> If the products are assembled in the manner indicated in specific ISSO Referentiedetails (or corresponding Product Details developed by ISSO and the manufacturer of the product), the indicated factor K may be used.

This method is very sensitive to changes in the mutual databases and therefore only prefers category 1 product cards in combination with product details.

- Indication of a minimum score of detachability in the applied ISSO Referentiedetails as a condition for applying the specified factor K; for example, at least category Good (see Figure 2.2) with a possible link with filter to the Referentiedetails. The filter in the ISSO Referentiedetails is not (yet) available but would be an extremely valuable addition as further development.
  This method would be suitable for category 2 and 3 cards because it automatically refers to changed or new ISSO-Referentiedetails.

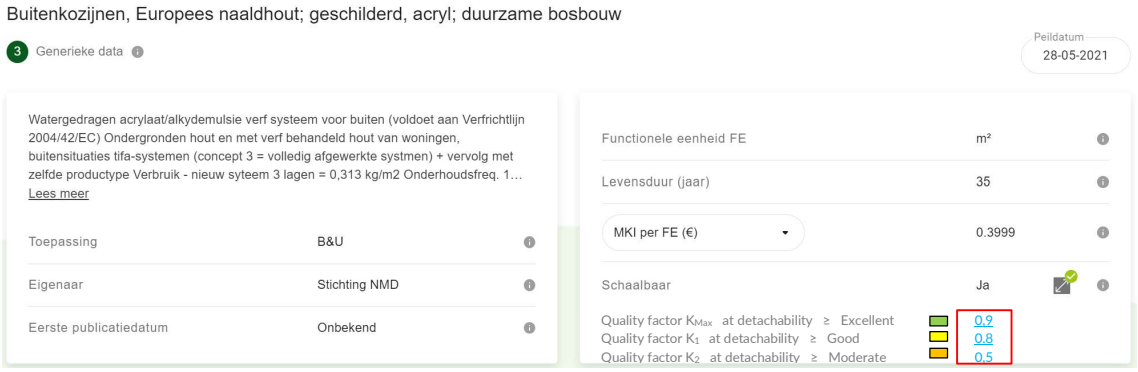

Figure 2. 8: Example of multiple possibilities factor K with indication of minimum detachability in Standard Referentiedetails with possible link to Standard Referentiedetails with set filter by product and minimum detachability index in the red box

2.5.4 Linking the ISSO Referentiedetails and the NMD

It would be good to be able to make direct links to product cards of the NMD from the ISSO Referentiedetails as well. In the ISSO Referentiedetails, one (or more) category 2 or 3 cards can then be referred to per product and in the Product Details you can then refer directly to category 1 cards. See below some examples of references to category 3 cards. The link may be located at the demarcation of the elements. It is not (yet) possible to create deep links to the correct product card(s) or, for example, with a set filter with all cards of this element with conditions set in the ISSO Referentiedetails. In a future project, this could be discussed with the NMD. Now examples have been given with screenshots from the NMD.

Furthermore, it is currently not technically possible to include links to the product cards within the online display of the ISSO Referentiedetails. This could also be taken up in a future project.

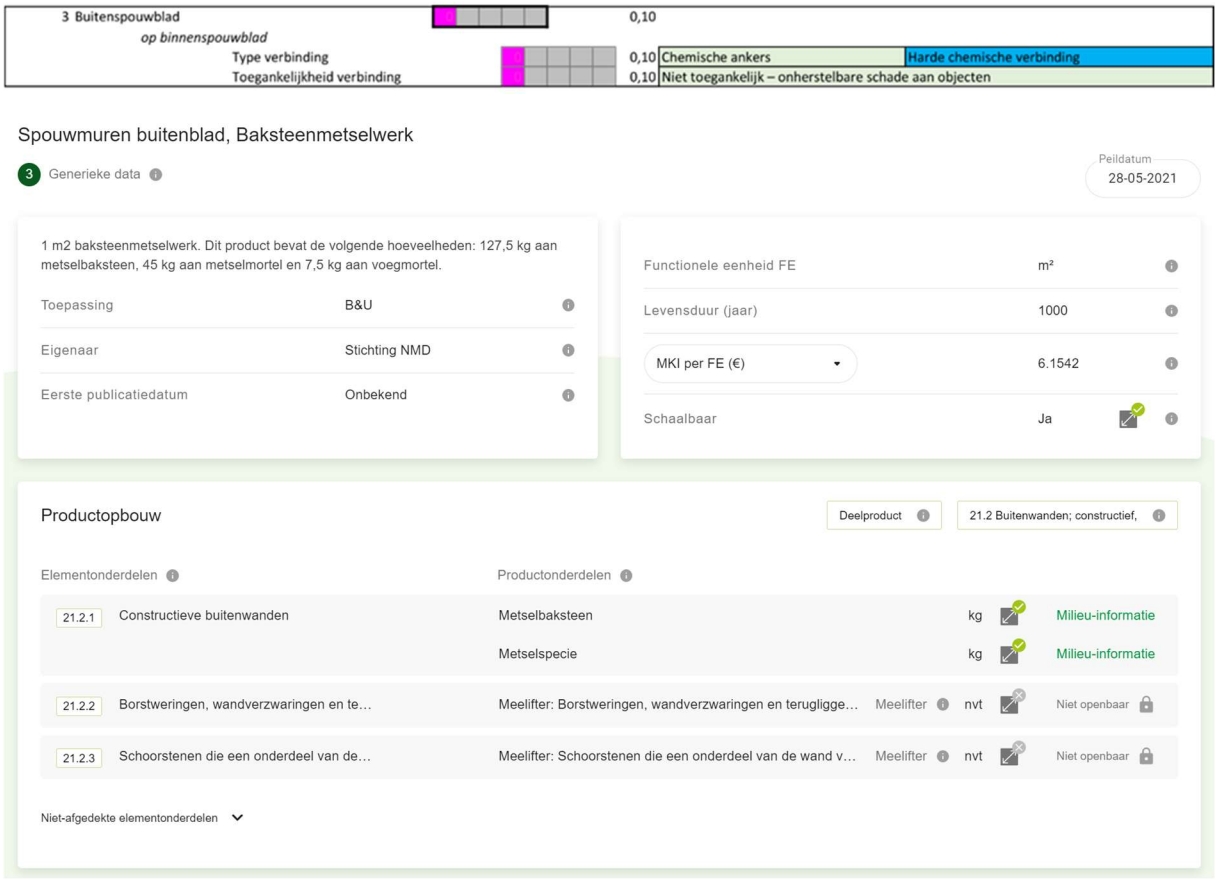

Figure 2. 9: Assessment of the element outer masonry wall in the example detail (Figure 2.3) with accompanying NMD product 3

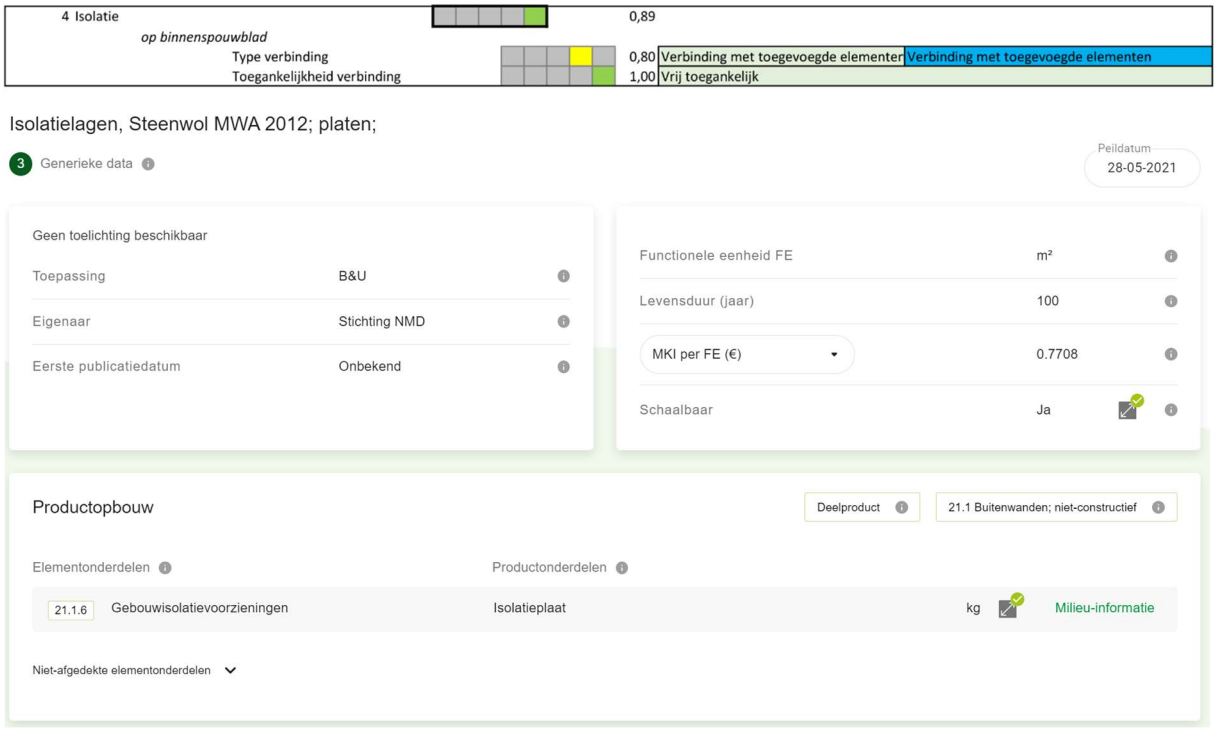

Figure 2. 10: Assessment of the element insulation in the example detail (Figure 2.3) with accompanying NMD product 3.

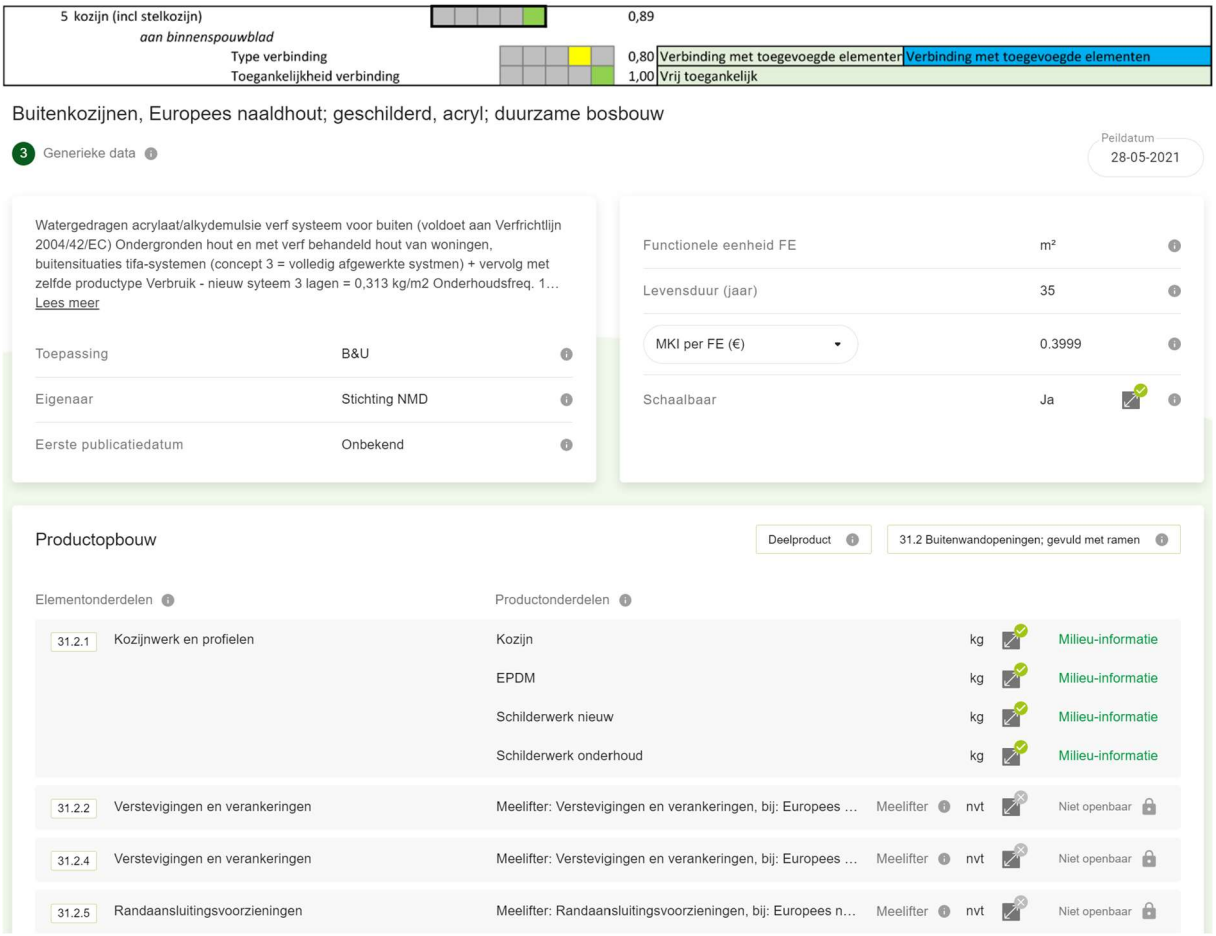

Figure 2. 11: Assessment of the frame element in the example detail (Figure 2.3) with accompanying NMD product 3.

3 IMPROVED DETAILS

3.1 OBJECTIVE

In this project, the focus was initially on determining the detachability of structural elements to be assembled on the construction site, as an important aspect of circularity. After the development of the determination method, it was applied to a number of existing ISSO Referentiedetails. In order to further investigate more detachable construction with a view to future reuse and to be able to compare the performance with regard to detachability with the basic details, a number of details with improved detachability have been developed. The main aim is to get a first impression of the possibilities for improved detachability for constructions and how the performance layers can serve as inspiration for the development of construction products, innovative construction methods and types of connections that could be further developed in (Dutch) construction practice.

3.2 CONDITIONS

- In the newly developed details, the starting point has been to use as many products as possible that are reusable after the life of the building. The products and systems used for this are:
    - Precast concrete walls
    - Precast concrete floors
    - Precast concrete foundation
    - Loose brick stacking system as façade finish
    - Closed siding, not specified
    - Hard foam insulation in the vertical cavity
    - Traditionally mounted wooden frames (pre-installation in the cavity)
    - Aluminium mounting window frames
    - Dry screeds
- Furthermore, the focus is on as many dry connections as possible between different parts. This has not always been possible, for example with fire-resistant seals.

3.3 RESULT

From each newly developed detail with improved detachability, two performance layers have been created:

- End-of-life
- Maintenance

4 COMPARISON OF EXISTING DETAILS AND IMPROVED DETAILS ON DETACHABILITY

4.1.1 End-of-life example

The assessment for detachability of the improved variant of the example detail of chapter 2 is given in Figure 4.1. The additional information shown in the downloaded PDF is displayed in Figure 4.2.

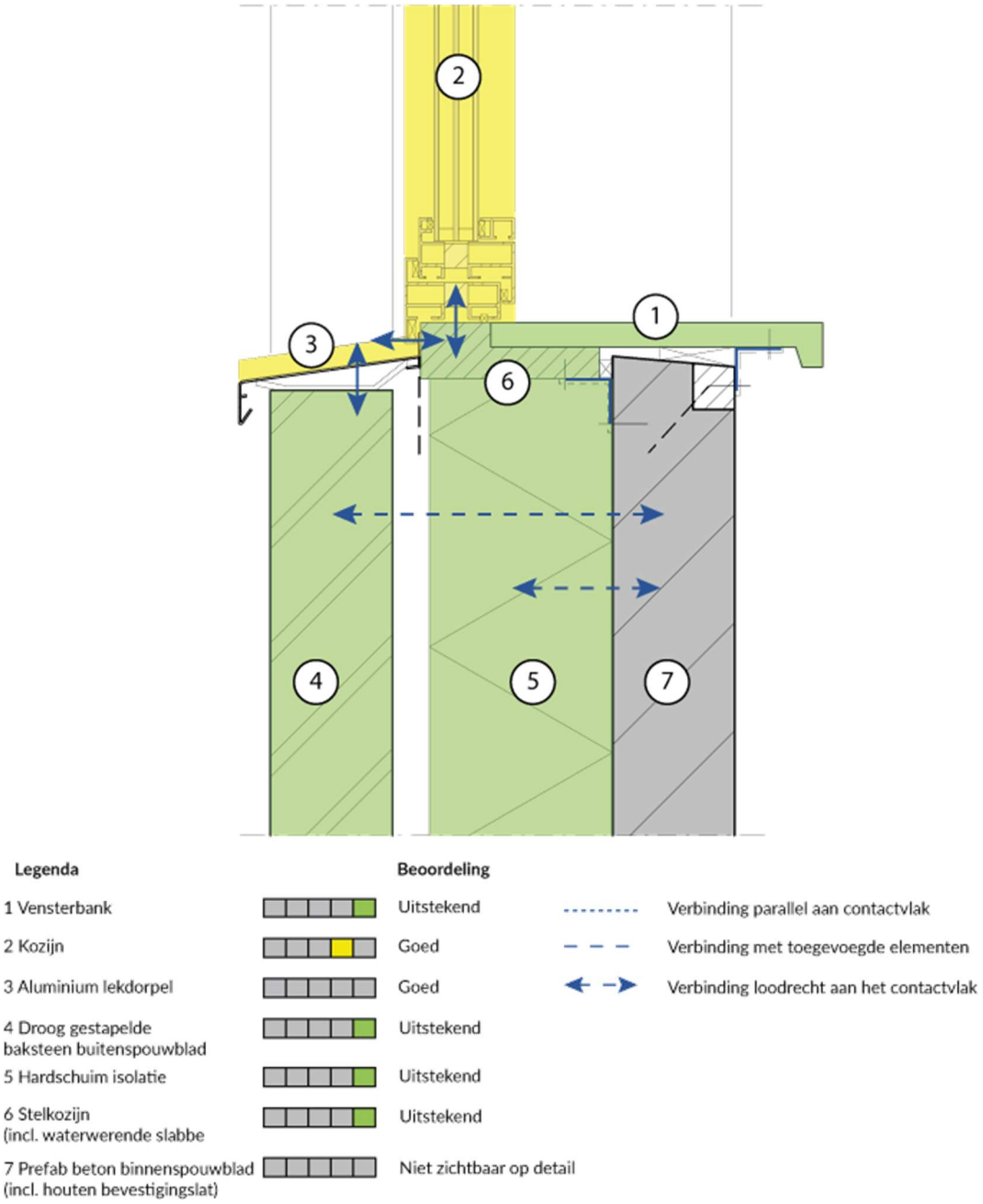

Figure 4. 1: Improved version of the example detail with performance layer detachability for the end-of-life scenario

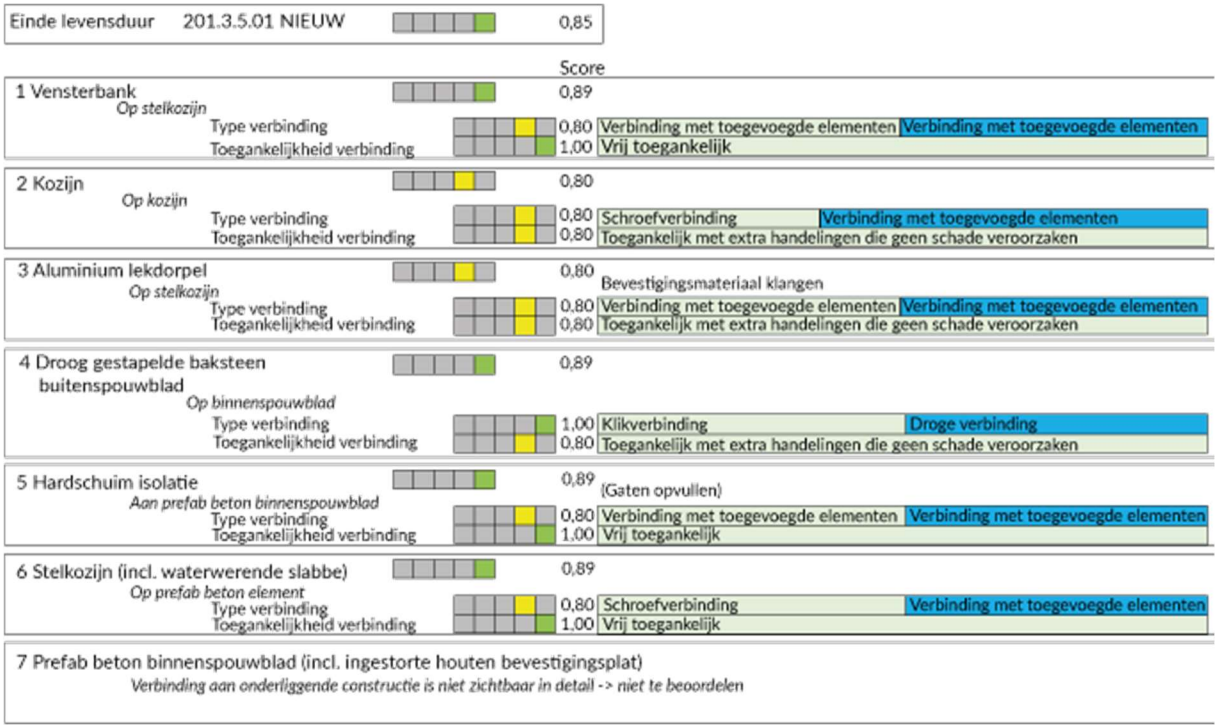

Figure 4. 2: details of the improved version of the example detail with performance layer detachability for the end-of-life scenario

The main point of attention for the detachability of the example detail of chapter 2, namely the masonry wall with chemical anchors is solved by working with a dry stacking system. With this, the score of the façade has gone from 0.1 (very bad) to 0.89 (excellent). Furthermore, the detachability of the window sill on the inside has been improved by clamping it under the frame and mounting it with an accessible corner profile at the bottom of the window sill so that the screw holes in the window sill do not have to be concealed and one no longer knows where they are when disassembling.

If one looks at the colors in the images, it becomes clear that where in the existing detail the colors purple (very bad) and orange (moderate) were still present, all elements are now green (excellent) or yellow (good).

Furthermore, it is striking that in the improved detail some more seperate elements have been added. This is due, for example, to the use of an assembly frame instead of a 'inmetsel' frame in which the adjustment frame is inseparably attached to the frame (with an adhesive connection) and forms one composite element.

In the improved detail, the frame can therefore be removed as second, after which the aluminum sill, the outer masonry wall and the insulation can be removed and only then the rest of the frame. This is particularly beneficial in the following scenario; maintenance.

The frame itself does have the rating of 0.8 (good) in the improved detail, which is lower than in the basic detail 0.89 (excellent). In the basic detail, the two frames form a whole and are mechanically fixed in the cavity. In the improved detail, additional operations must be carried out to get to the connection between the two frames.

Note: Figure 4.2 shows a total score of the detail. This number now results from equal weighting of all elements. Some elements will have more influence on the total detachability of the building than others, for example because they occur more often or because the product to be reused has a higher environmental impact. This total score is therefore no more than an indication. The added value of displaying the detachability in the ISSO Referentiedetails lies mainly in the visualization with the colors in the detail itself to see where the problems arise.

4.1.2 Example maintenance and management

In Figure 4.3 the assessment for detachability is given of the improved variant of the example detail of chapter 2 for the scenario 'maintenance'. The additional information shown in the downloaded PDF is shown in Figure 4.4.

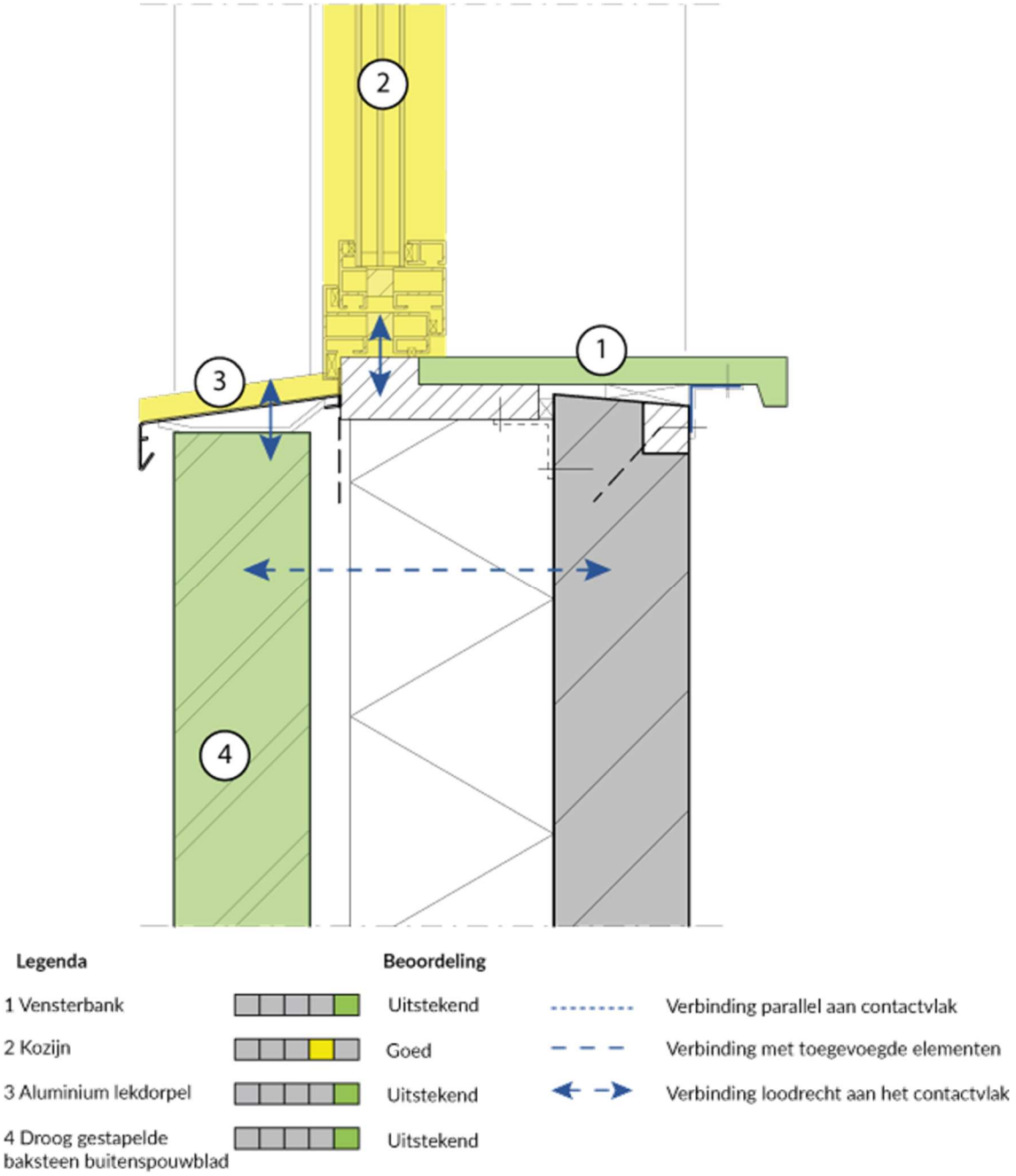

Figure 4. 3: Improved version of the example detail with performance layer detachability for the maintenance scenario

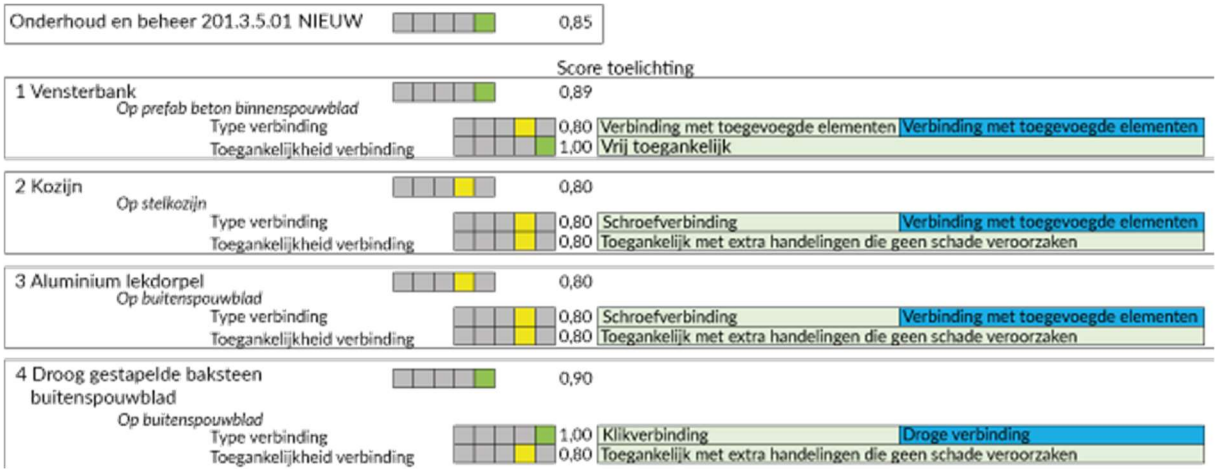

Figure 4.4:Details of the improved version of the example detail with performance layer detachability for the maintenance scenario

From the comparison of the detachability during maintenance and management of the existing example detail (figure 2.5) and the improved version (figure 4.3) it can be immediately concluded that:

- more elements are eligible for replacement. The outer masonry wall can also be replaced by, for example, bricks with a different color.
- the parts are easily detachable and the score is equal to the end-of-life scenario because the connections of the elements are also easily accessible without having to remove other elements.

It was decided not to assess the replacement of the stelkozijn in the maintenance scenario. With renovation, this would make sense. The detachability for this scenario can be further improved.

Figure 4.4 provides a total score of the detail. This number now results from equal weighting of all elements. Some elements will have more influence on the total detachability of the building than others, for example because they occur more often or because the product to be reused has a higher environmental impact. This total score is therefore no more than an indication. The added value of displaying the detachability in the ISSO Referentiedetails lies mainly in the visualization with the colors in the detail itself to see where the problems arise.

5 CONCLUSIONS AND FOLLOW-UP

This project has led to:

- Increasing knowledge about building techniques to facilitate disassembly and improve the durability and adaptability of a building (H2 E).
    - By visualizing the detachability in the Standard Referentiedetails of ISSO, the points where the detachability is poor can be better identified.
    - This makes it easier to find solutions for innovations.
    - A number of examples of improvements for detachability have been developed and assessed using this method
- Sharing information to increase environmental performance of buildings with better design (H2 F).
    - The methodology will be shared at ISSO Open with examples of assessment of existing details (see Annex A) and newly developed details (see Annex B)
- Facilitate the design of products and systems so that they can be easily reused, repaired, recycled or recovered (H2 H).
    - In the future, the possibilities can be explored that make the information even more accessible by, for example, adding a filter so that details with a certain performance in terms of detachability can be searched.

5.1 CONTINUATION

- In a follow-up project, as indicated in section 2.6, the connection can be made with other aspects of circularity, for example with the MPG calculations and the preparation of LCAs so that not only detachability, but also the materials themselves are looked at;
- Research can be carried out to the need and possibilities to assess innovative forms of fastening methods and means, with extra attention to airtightness;
- The inclusion of an index for the time and labor required of the 'extra actions' to get to a connection;
- More existing details can be reviewed in the future;
- Manufacturers who design smart and detachable products can also have product details created and reviewed.
- The details and information can be made interactive, making it possible to filter by performance and construction method and where corresponding details can be searched (e.g. top, bottom and side). This is a functionality that requires a major adjustment for the organizational structure of the Reference Details in general and will therefore have to be part of an overall further development of the reference details.
- Bringing with you practical experiences from, among others, dismantling companies.

REFERENCES

[1] I. E. a. S. European Commission of Internal Market, "Circular economy principles for building design," 2020.

[2] A. Concepts, "Circular buildings - Meetmethodiek losmaakbaarheid (v 2.0)," 2021.

[3] S. Brand, How Buildings Learn: What Happens After They're Built, Penguin Books, 1995.

ATTACHMENTS

Bijlage A. **Performance layers 'disassembly' of 13 Existing ISSO-Referentiedetails**

Bijlage B. **Basic drawings 15 new m. b. t. detachment of improved ISSO Referencedetails**

Bijlage C. **performance layers 'disassembly' 15 new m.b.t. detachability improved ISSO Referentiedetails**