Foundation Decarbonization and Re-use

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Foundation optimization is a concept that has been applied for as long as foundations have been designed. Obviously a foundation has to able to withstand the loading of the superstructure, but if it is overdesigned then the cost and the effort to construct that foundation will increase unnecessarily. As a result, foundation engineers are always attempting to find the “goldilocks” foundation: not too big, not too small, but just right. This optimization effort also fits perfectly with the sustainability effort: a smaller foundation uses less materials and is therefore more sustainable. Moreover, concrete and steel, the materials commonly used for foundations, both have a relatively large carbon footprint, which reinforces the need to optimize the foundation when the environmental impact of a particular construction project is assessed.

Apart from optimization the foundation size, the material selection also affects the carbon footprint of a foundation, and there are numerous examples of ways to decarbonize the foundation in this manner. The use of fly ash or metal slag as cementious material in concrete, the use of recycled concrete aggregate and recycled steel, and the use of timber piles are just a few of the many options engineers have available when it comes to decarbonization.

Taken together, that is optimizing the size and (re-)using materials that decarbonize the foundation, this approach fits perfectly in the waste hierarchy as illustrated in Figure 1. This concept, which is a key element of the so-called circular economy, ranks options to manage waste materials from most to least preferable based on the environmental impact. This waste hierarchy is a regular feature whenever the sustainability aspects of foundations is discussed, and it was therefore not surprising that it was mentioned repeatedly at a conference organized by the Deep Foundation Institute (DFI) and the European Federation of Foundation Contractors (EFFC) in Berlin, Germany in May 2022. At this conference there was a workshop on sustainability the day before the conference started, followed by two panel discussions on sustainability during the opening day. However, as is the case at most of these events, a very logical option to provide for a more sustainable solution, that is the reuse of an already existing foundation, got little attention.

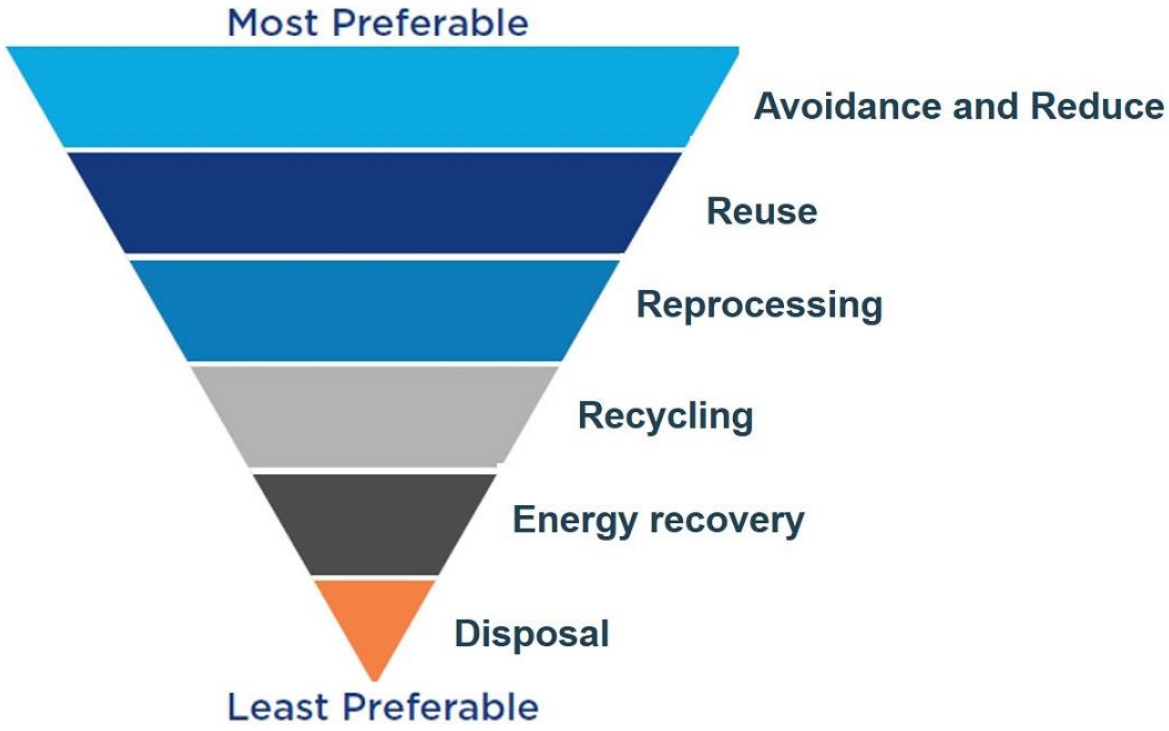

Figure 1: Waste Hierarchy Pyramid

To ensure that the option of foundation reuse would be addressed, DFI together with the geotechnical section of the Dutch engineering society KIVI hosted the Conference on Foundation Decarbonization and Reuse in Amsterdam, The Netherlands, in March of this year (see Figure 2). During the first two days the conference topic was covered in 4 sessions, starting with the overall concept of foundation decarbonization and reuse, followed by the assessment of existing foundations, and the design aspects associated with this topic, and finally the impact this approach will have on the construction phase. Each session was opened by a keynote speaker, after which papers from all around the world (including a submission from Canada by Tony Sangiuliano with the Ministry of Transportation in Ontario) were presented. The session then closed with an extended Q&A session with all those that had made a presentation in that particular session.

Figure 2: Banner Conference on Foundation Decarbonization and Reuse

The concept

What became very apparent during the conference was that the project owner's role is essential when it comes to foundation reuse. After all, for the foundation designer the reuse of foundation is associated with (the perception of) additional risk, while for the contractor foundation reuse means a reduction in his project scope and therefore a lower contract value. It was therefore appropriate that the keynote speaker for the opening represented an owner. Jan-Jacob van Blijswijk with Shell Moerdijk in The Netherlands used as the basis for his presentation a recurring scenario for Shell: whenever a refinery a process unit needs to be replaced by a larger and/or more efficient unit, the current foundation should be reused for that new process unit if at all possible. In his presentation he described a six-steps process (as illustrated in Figure 3) that is followed to explore for a particular project whether foundation reuse is feasible, whether the existing foundation has to be repaired or supplemented when it to be reused, and finally how the foundation reuse is then implemented. The crucial step in that process is the assessment, when all parties get together to provide an overview of all the potential options available. In this step it is essential that all aspects associated with the project (i.e., design, construction and operation following completion) are carefully considered to ensure that as part of the next step the optimal solution can be identified. This means that as part of the assessment the various risks are identified, which also requires an assessment of the existing foundation.

Figure 3: Shell's Process for Foundation Reuse

The Inspection and Testing of an Existing Foundation

In his keynote address that opened the second session, Marcel Bielefeld with Allnamics Geotechnical and Pile Testing Experts in The Netherlands, emphasized that the inspection and testing of the existing foundation go beyond determining the foundation's condition (see Figure 4). They also require determination how the foundation was originally installed (e.g., through as-built drawings after ensuring that those drawings indeed reflect the as-built situation or through partial excavation) and the verification of the actual size and length of the foundation elements as well as the bearing capacity of the foundation (incl. the anticipated settlement under the new working loads). Assuming that all these aspects can be addressed, the outstanding question is then the remaining service life of the foundation. That question was addressed in several papers that were presented during the session. In his presentation Tony Sangiuliano with the Ministry of Transportation in Ontario discussed how the remaining lifetime was determined for the steel piles that were reused for the Greenock Creek Bridge in Walkerton, Ontario, while other speakers covered how concrete and timber piles can be inspected to assess the remaining lifetime. For the latter pile type, the Dutch approach to classify the quality of a timber pile foundation was presented, which combines the condition of the timber pile (through the use of an impact hammer) with the anticipated foundation settlement under the new working loads.

Figure 4: Inspection of an Existing Timber Pile Foundation

The Design Aspects of Foundation Reuse

The third session covered the design and engineering aspects associated with foundation reuse. Henry Tayler with Arup in the United Kingdom opened that session by providing a perspective on barriers, enablers and risk management through the design process when foundations are reused. In his presentation he showed the decision tree for design approaches to existing structures/buildings (see Figure 5), which was published by the Greater London Authority in 2022 as part of their guidance on the circular economy. He also reminded the attendees once more that "redevelopment and regeneration of urban areas have left a legacy of old foundations, congested underground space and archaeological artefacts. This legacy compromises new developments and the project 'Reuse of Foundations for Urban Sites' (RuFUS), partly funded by the EU, developed and proving new processes to provide environmentally sustainable foundations for future developments", which were published in 2006.

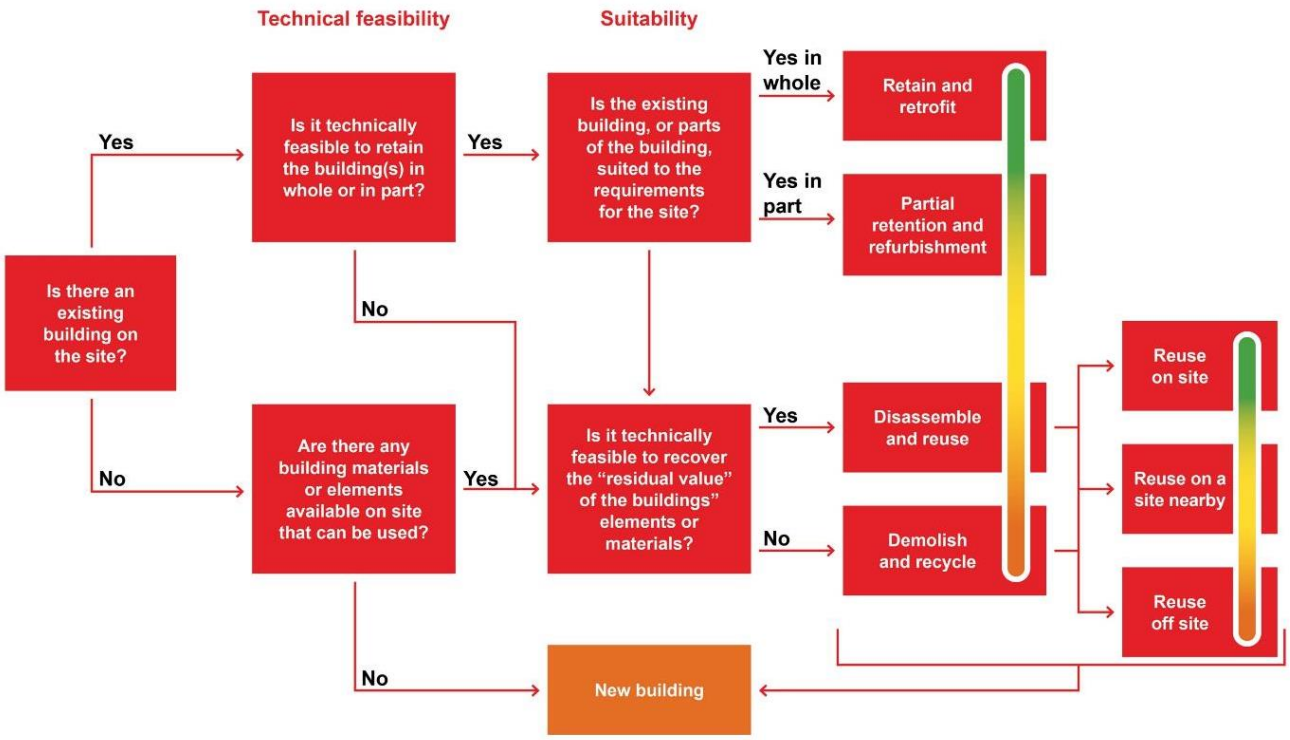

Figure 5: Decision Tree for Design Approaches to Existing Structures/Buildings
(source GLA Circular Economy Guidance)

During the session there was also a presentation on the Carbon Calculator, a simple tool developed by DFI and EFFC to calculate the CO2 emissions of foundation and geotechnical works (www.effc.org/how-we-operate/eco$_2$-foundations/). It was developed using verifiable, standardised data to enable accurate benchmarking of competing project proposals, and it allows contractors to compare and contrast different technical approaches within the same project and see what the CO2 emissions will be.

The Construction Aspects of Foundation Reuse

The final session of the conference was opened by Patrick IJnsen of Van 't Hek in The Netherlands, kicking off the discussion on the construction aspects. His presentation clearly stated the dilemma for a construction contractor. As he put it, "re-use of deep foundations can have a positive impact on a client's budget; however, for the contractor it (only) brings uncertainty:

- What will it cost to make it fit for another service life?
- Can all elements be used or do we need to replace some?
- What time is required for inspection, and what do we find?

But recognizing that foundation decarbonization and reuse is going to happen, he presented his views on how contractors can best deal with this concept. He emphasized the needs for maintaining foundation archives with material certificates, (accurate) as-built drawings and construction logs, which are critical to make foundation

reuse a success. Regarding decarbonization he referred to the Carbon Reduction Guide issued by EFFC in 2022, which will become part of a series of guides that will be prepared by DFI and EFFC jointly to cover all 17 Sustainable Development Goals as defined by the United Nations.

After two days of presentations (which together with the papers themselves can be found on the conference website www.foundationreuse.com), the third day offered the attendees an opportunity to visit several sites and projects in and around Amsterdam to give an impression of the possibilities of reducing decarbonization by re-using existing foundations. The program offered several tours, each with its own focus and the participants could select one tour in the morning and another in the afternoon.

The conference program as a whole provided the participants a good overview of the topic and the feedback was such that the organizers have decided to hold what will be the second annual Conference on Foundation Decarbonization and Reuse. The event will once again take place in Amsterdam and be held May 28 – 30, 2024. The structure will be very similar to what was described in this article, but in addition there will be a panel discussion where the owner with his legal representation will discuss with an architect, a structural engineer, and a geotechnical engineer the options to repurpose an existing structure that involves the reuse of the foundation. This panel discussion will be added in response to the feedback from the attendees at the end of the conference, as this interaction was seen as a missing element in the program. More information on the event can be found on the conference website www.foundationreuse.com. The organizers also intend to have this website serve as a resource center for foundation reuse. As such it will allow for the free download of all documents in the library and suggestions to add documents are always welcome.