Steered Erosion – A differentiated approach on weather protection for exposed rammed earth walls

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Abstract. For environmental as well as aesthetic reasons, the use of rammed earth has become increasingly popular in the last years. However, there is still a lot of insecurity among clients, planners and contractors concerning the material’s weather resistance, which impedes its wider application. Starting from here, the paper investigates different construction-related strategies of weather protection that build upon the idea of Calculated Erosion described by rammed earth pioneer Martin Rauch. Through the development of a typology of techniques as well as application studies, the paper shows how on one hand, increased protection can ensure the durability of a wall even under heavy rain impact, while on the other hand – in case of little exposure – erosion can explicitly be permitted, allowing for a strong aesthetic expression of the natural process. Introducing the concept of Steered Erosion as an extension of Calculated Erosion, weather protection techniques are conceived as both functional and design-related interventions in the erosion process, which together are able to significantly promote the use of rammed earth as a sustainable building material.

Keywords: process, scenario analyses, rammed earth, erosion, material cycle

1. Introduction

The use of pure, non-stabilized rammed earth for exterior building walls has become more and more popular in recent years (see, for instance: Alnatura Arbeitswelt, Darmstadt, Germany [1]; Ricola Kräuterzentrum, Laufen, Switzerland [2]; Haus Rauch, Schlins, Austria [3]). Exposed rammed earth walls are valued for their monolithic presence and the aesthetics that come with the aging of the surface due to natural erosion, and they enable a simple way of building that perfectly fits circular construction ideals. They are usually realized following the concept of Calculated Erosion described by rammed earth pioneer Martin Rauch, using so-called Erosion Checks in the façade (figure 1) [4].

However, due to a lack of research on the resistance of the material against driving rain, different opinions exist among experts [5][6][7], and there is still a lot of insecurity among clients, planners and contractors regarding its exposed use. Moreover, while Calculated Erosion is usually applied uniformly, the actual driving rain stress varies strongly depending on the local context [8][9].
Starting from these observations, the research presented in this paper raises the question of how the idea of Calculated Erosion – and specifically the use of Erosion Checks – could be extended to allow for a greater flexibility in responding to specific site conditions. To answer this question, the research design comprised of the development of a typology of tools in combination with graphic application studies (figure 2). For these tools, the new term Erosion Bar was introduced, denoting elements similar to the classic Erosion Check, which, beyond slowing down water runoff, act in different ways as a (constructive) erosion protection. The typology represents a theoretical framework for recording and ordering different basic types of Erosion Bars and is meant to be an open system which can easily be extended. Through the application studies, the different types were tested regarding functional as well as design aspects, and they also served as a verification of the typological order. Focus was put on a qualitative consideration with the aim of a rough comparability of the investigated tools, and a derivability of basic application potentials. The investigations built upon some of the author’s earlier practical research [10][11], which enabled an estimation of the influence of the examined techniques on the erosion process. Drawing-based studies were preferred over practical tests in order to be able to examine a sufficiently wide range of Erosion Bars as well as a larger surface area, which seemed necessary for a meaningful evaluation of results in the scope of the research project.

The aim of the investigations was to develop a series of Erosion Bars which help increase planning reliability, but also take advantage of the aesthetic potential of the erosion process, in order to further propagate the use of rammed earth. Therefore, an integrated approach considering both functional and design-related aspects of use – particularly the indirect aesthetic effect, i.e. the effect the Erosion Bars have on the appearance of the wall surface by means of the erosion process – was of central importance.
2. Methods
The investigations presented in this paper were undertaken using the example of rammed earth masonry construction, i.e. construction with small-format prefabricated rammed earth elements. The typology of Erosion Bars was developed using two main classification criteria that appeared to be most suitable for a classification: the mode of action of the Bar – that is, the way in which it exerts erosion protection and at the same time indirectly effects the appearance of the wall surface – and the manufacturing method. The application studies were based on the example of a two-story exterior building wall, whereby only a section of the lower wall area was considered. One exemplary study was prepared for each Erosion Bar type, the respective design being based on fundamental design assumptions following studies on fabrication and constructive detailing. In order to illustrate the influence of erosion, the appearance of the wall surface at construction completion and the assumed appearance at an advanced stage of the erosion process (after a few years) were represented in elevation and sectional drawings. For this latter condition, an estimate of the depth and distribution of erosion – merely to be understood as rough approximations to reality – was made based on the volume and vertical travel length of the water flowing down. According to assumed erosion depths, specific hatch densities and colors were used for the elevation drawings (figure 3).

![Figure 3. Different hatches associated with estimated erosion depths.](image)

3. Results
For the overview of Erosion Bars presented through the typology, traditional techniques from vernacular architecture as well as techniques from landscape design (for protection against soil erosion) served as models and references (figure 4 a-g) [12]-[18]. Among these, three different primary modes of action could be identified, which were then adopted for the typological order. These modes of action are the protection of the surface against hitting water (shielding), the redirection and bundling of the water flowing down the wall surface (draining), and the slowing down of the water flow (retarding). Further, different sub-forms were defined, which mainly respond to the special case of rammed earth masonry.

![Figure 4. Erosion Bars: Precursors and references.](image)
Regarding the second ordering criterion of the typology, the manufacturing method, a basic distinction was made between a mortar Bar and a prefabricated Bar. For the prefabricated Bar, a further distinction was made between a jointing during wall construction and a prior jointing during production of the earth block (composite).

The identification of possible combinations of the two ordering criteria (mode of action + manufacturing method) resulted in an overview of 12 different types of Erosion Bars (figure 5).

The application studies showed clear differences both in the degree of protection that the Erosion Bars provide, and the indirect effect they have on the appearance of the wall surface. A rough classification in this regard is shown in figure 6, also illustrating a basic correlation: the lower the protective effect of the Erosion Bar, the higher its influence on the façade appearance.
Figure 6. Grading of types regarding surface protection and indirect aesthetic effect.

While type Su–Pj, for instance, provides almost complete protection of the surface against driving rain – which results in almost no erosion – type Rn–M offers hardly any protection, but has a huge influence on the morphology of the wall surface. In the application study for type Su–Pj (figure 7), the amount of overhang of the Bar over the façade is chosen so that the complete surface is protected from driving rain under average circumstances, and only very minor erosion is to be expected in the lowermost area of each masonry layer. On the contrary, the study for type Rn–M (figure 8) shows strong erosion in parts of the wall surface, due to the mortar Erosion Bar receding from the surface, letting the erosion process “shape” the wall surface to a certain extent.

Figure 7. Application study for type Su–Pj (before/after erosion).
Two types which show a balance between the two opposing effects of erosion protection and indirect aesthetic effect are types $Sn-Pj$ and $Su-Pj$. $Sn-Pj$ (figure 9) is a modification of type $Su-Pj$, in which the amount of protrusion of the Bar varies along the wall axis, in order to provide maximum protection only for the areas around the vertical masonry joints, which deserve special care. As a consequence of the varying protective effect, a non-uniform erosion pattern is created on the wall surface.
The $Ds$–$Pj$ application study (figure 10) shows another kind of non-uniform erosion protection. Here the rainwater runoff is diverted along the wall axis, bundled, and discharged downward at the center of each masonry block. While the majority of the surface, even of the lower masonry layers, experiences only minor erosion, stronger washout is to be expected in the areas of concentrated water flow. This weighting of erosion stress on the surface creates a distinct façade appearance.

![Figure 10. Application study for type $Ds$–$Pj$ (before/after erosion).](image)

4. **Discussion**

The techniques presented in this paper show a variety of possibilities of dealing with erosion on exposed rammed earth walls. It becomes clear that Erosion Bars – as tools for intervening into the natural process – offer valid solutions to the problem of weathering, since they enable a flexible response to differing site conditions. Where necessary, i.e., in heavily exposed locations and on weather-side façades, a high degree of erosion protection can be implemented, so that almost no erosion occurs. On the other hand, where possible and appropriate (such as on less exposed façades), stronger erosion can be permitted by using Erosion Bars with a higher indirect aesthetic effect. According to DIN EN ISO 15927-3, for instance, driving rain loads can vary by a factor of 5 due to the presence of obstacles (i.e. other buildings, trees etc.) in the immediate surroundings [8]. Studies at Fraunhofer Institute for building physics even indicate that non-weather side rain loads amount to just 2 – 8 % of the load on the weather side of the respective building [9]. In any case, surface erosion of the amount discussed in this paper doesn’t compromise the wall’s functional and structural capabilities. Today, high security factors are included in their structural calculation, which generally leads to heavy over-dimensioning.

The presented techniques expand the idea of Calculated Erosion (figure 6) to a concept of controlling erosion – or Steered Erosion – which enables differentiated interventions in the erosion process, taking equal account of functional and aesthetic aspects.

In this sense, an analogy to landscape design can be drawn. In the design of urban river basins for instance, functional and design-related interventions in the natural process play an important role. For the specific context, Prominski et al. developed so-called process boundaries which define a space
within which erosion processes in the riverbed are tolerated [19]. As a concrete means of implementing Steered Erosion, the Erosion Bars set precisely these boundaries for the erosion process of the rammed earth façade.

By employing the concept of Steered Erosion, the acceptance of rammed earth as a building material is thus promoted in two different ways. Firstly, a significant expansion of the weathered use of the material is made possible, and through this, an increase in trust in its performance. By realizing high degrees of erosion protection in respective local situations, adequate planning security can be provided. This is critical since to date, there is little regulation regarding the use of exposed rammed earth walls. In Germany for instance, it is not covered by *Lehmbau Regeln* [20] and therefore represents an exemption in building law, which can mean a high barrier for the realization of projects. Also, the possibility of implementing a high degree of control takes on importance due to the fact that, as a result of climate change, weather extremes such as heavy rainfall events will likely be more frequent in the future [21].

Secondly, the reputation of the material is nurtured through its aesthetic appeal. By harnessing the form-generating potential of the erosion process, the full aesthetic potential of rammed earth can be utilized, and erosion – as architect Anna Heringer for instance calls for [22] – celebrated as part of the material’s natural cycle (figure 11), raising awareness for a truly sustainable, circular building practice.

![Figure 11. Material cycle of clay.](image)

5. Conclusion
Addressing the current lack of confidence in the weather resistance of non-stabilized rammed earth, this paper investigates different construction-related strategies of weather protection that build upon the idea of Calculated Erosion. Through the development of a typology of techniques as well as application studies, it shows how on one hand, increased protection can ensure the durability of a wall even under heavy rain impact, while on the other hand – in case of little exposure – erosion can explicitly be permitted, allowing for a strong aesthetic expression of the natural process. Introducing the concept of Steered Erosion as an extension of Calculated Erosion, weather protection techniques are conceived as both functional and design-related interventions in the erosion process, which together are able to significantly promote the use of rammed earth.

Beyond the scope of the industrialized countries, the concept of Steered Erosion might also help boosting the use of earth in other parts of the world, especially the global south, where the building
material often has a low reputation. Furthermore, it provides an impetus for a change in the way we deal with the aging of building materials in general. Many modern building envelopes have relatively low durability because they do not have strategies for dealing with aging. A greater focus on the aging process of buildings is necessary in order to reduce the negative effects of the building sector on the environment.

As far as limitations are concerned, only the direct influence of driving rain was considered within the scope of the presented investigations. Other factors of surface erosion such as frost (and in this respect the importance of the water absorption capacity of rammed earth according to DIN 4108-3) were not taken into account. Practical investigations under natural conditions over a longer period of time will be an indispensable next step. Follow-up research using demonstrators in long-term tests is currently being planned by the author.

Note: This paper is based on research done in the course of a dissertation project at the Chair of Building Construction, Faculty of Architecture, RWTH Aachen University. For a comprehensive and detailed description of all aspects mentioned, please see [11].

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