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SINTEF Academic Press

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ZEB Project report 12 – 2013

ZEB Project report no 12

Åshild Lappegard Hauge²⁾, Åsne Lund Godbolt²⁾, Judith Thomsen²⁾, Thomas Berker¹⁾, Berit Time²⁾ og Oddvar Hyrve (Weber)

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Abstract

This is an early user test of vacuum insulation embedded in clay blocks, a solution developed within ZEB. The product is in an early stage of its development and is not taken into use in any building projects yet. Therefore, the evaluation is not based on experiences but on expectations towards this product. In this exploration we have conducted twelve telephone interviews with representatives from different parts of the building industry. The main results are: There is general agreement that vacuum insulation will be interesting and attractive for the market. Some find thick walls problematic, but others indicated that there exist aesthetic and practical reasons to prefer thick walls. Vacuum insulation may therefore be especially important for renovation projects and new buildings where the site costs are high. Vacuum insulation in clay blocks seems like a reasonable combination to most of the informants. But there was also a demand for vacuum insulation for wood constructions in combination with thinner and lighter materials. According to our informants, to make vacuum insulation a central building product in the future, a great degree of material flexibility will clearly be important. For future promotion of a product with vacuum insulation, it is also important to convince the market that it is robust enough, and show calculation examples on how the product may be more profitable when used where the site prices are high. The environmental impact of vacuum insulation matters to some of our informants, and a clear plan for pre-separation at source is asked for.

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1. Introduction

One of the assignments in ZEB, Work package 4.1 "Use of zero emission buildings", is user testing of solutions developed/used in ZEB-related work.

In close collaboration with the other work packages in the project and industry partners, the researchers want to test early prototypes or selected aspects of solutions developed there. The respective test subjects, the experimental setting and the test objectives depend on the type of solution tested.

One of the main arguments for doing this is that early testing is a very cost-efficient way of gaining insights into end-use-related advantages/challenges.

1.1 Choice of product for the user test

In cooperation with the other researchers who work in ZEB, it was suggested that **vacuum insulation in expanded clay aggregates, Leca blocks**, was suitable and interesting for user evaluation. At the present moment, this is one of the most defined products/solutions that have been developed in ZEB, and one of the products closest to market introduction.

Vacuum insulation in expanded clay aggregates is tested in WP2 in ZEB. The ZEB partner Weber patented the product. In Norwegian, the product is named "Leca Isoblokk VIP".

- Leca Isoblokk VIP is used for outer walls above and below ground.
- Leca Isoblokk VIP is developed to achieve a wall with low U-values and reduced wall thickness.
- Leca Isoblokk VIP makes it possible to reduce thickness and thereby the volume of the wall construction.
- The U-value for 250 mm Leca Isoblokk wall with VIP is measured to 0,14 W/m²K.
- The U-value for 250 mm regular Leca Isoblokk wall is 0,29 W/m²K.
- The VIP-panel has 5 to 10 times better insulation values than mineral wool.
- A disadvantage is that the product cannot be cut in at the building site. The foil that surrounds the silicon core has to be intact.
- The greenhouse gas emission (CO₂) in production is larger (per kg) than for traditional insulation materials.
- VIP-panels are more expensive than traditional insulation materials, but the prize may be competitive in living areas where the m²-prizes are high.
- According to the producer the Leca block with vacuum insulation is not primarily a product for renovation, but for new constructions.

1.2 Background

Weber St. Gobain has worked with the idea of vacuum insulation in Leca blocks since 2007. As a partner in the research project ZEB, they saw an opportunity to test the durability of their product.

However, a pilot interview with representatives from Weber showed that the timing for a "market survey" was not right yet. According to them, too many aspects of the product were unclear and the tests on durability were not finished and the product was therefore not yet ready for the market (per June 2013). Their aim is that the product should have at least 60–100 years in documented length of life. The status of this essential aspect is still uncertain, and more information is needed before a market survey is carried out.

A driver behind the development of the product is the forthcoming building regulations about passive house standards. Weber wants to be able to make it possible for consumers to build thinner walls than today, with the same insulation effect. This is especially critical in cities where the site costs are high. More effective use of the site area will compensate for the possible higher price of the building material with vacuum insulation. According to the producer, the market interest for a product like this depends on how important it is for consumers to have thinner, but also more expensive walls. Is a thinner wall seen as more attractive for the resident/ end user aesthetically? Will a thinner wall give a better experience of for instance daylight?

Weber sees the risk for puncturing as a rather small problem. Very few things are drilled deep into the wall, so the problem is not relevant for the end user. Obviously, the workers at the building site have to be careful when cutting the blocks. However, because of the composite nature of the block, if an element should puncture, the wall as a whole would still maintain good insulation capability.

The interview guide that was used in the following empirical exploration of expectations held by different actors within the building sector was based on the questions Weber stressed. Because of the producer's assumption that the actual product is not ready for a market test, it was decided to make the user evaluation more general. The user test of the product was therefore focused on a discussion on the need for reducing wall thickness – and the cost aspect, more specifically it was asked:

- Is the building market interested in products that diminish the wall size and improve the insulation values? How important is a product like this for the market?
- What costs are they willing to accept for a product like this?
- How critical is the vulnerability of a hypothetical product that consists of vacuum insulation wrapped in clay blocks?
- A product like this will have more extensive greenhouse gas emissions compared to traditional products. How does this influence the evaluation of vacuum insulation in clay aggregates?

A more general product description about "vacuum insulation in clay blocks" was therefore sent out before the interviews:

- In the research center ZEB, researchers are developing vacuum insulation to reduce wall thickness.
- Vacuum insulation may for example be put inside of Leca blocks, see photo.
- These insulation blocks will have low U-value and make it possible to reduce wall thickness and the volume of the wall construction.
- The insulation blocks may have 5 to 10 times better insulation values than mineral wool.
- Vacuum insulation loses its high insulation ability if it is cut at the building site. A disadvantage is that the product cannot be cut in at the building site. The foil that surrounds the silicon core has to be intact.
- The greenhouse gas emission (CO₂) is larger (per kg) than for traditional insulation materials.
- VIP-panels are more expensive than traditional insulation materials, but the prize may be competitive in areas where the m²-prices are high.



2. Method

2.1 Qualitative interviews

The user evaluation is based on qualitative interviews of relevant actors in the building industry. This is a small pilot study with limited time frame. Therefore, most of the interviews were conducted by telephone.

The user test was explorative in nature, seeking thoughts and attitudes towards a new type of product. Qualitative interviewing was therefore the most promising method. Themes and meanings in the interviews were written down, grouped, analysed and discussed. The results from the case studies/ interviews can be generalized through *analytical generalization*, meaning that the findings from one study can be used as a guide to what might occur in other, similar situations (Kvale, 1996).

2.2 Choice of informants

Since the product was not taken into use in any building projects yet, it was decided to make the user evaluation hypothetically, and interview different representatives from the building industry. The intention was to shed light on different perspectives on the product from different hypothetical users. The interviews can be characterized as expert interviews. The informants consisted of:

- 7 members of the reference group for ZEB (representatives from the building industry on different levels)
- 2 Architects
- 2 Building contractors
- Weber, product developer, vacuum insulation (group interview with 3 representatives)

Totally 12 interviews were conducted.

2.3 Questions

The interviews had four main topics, and the informants were free to talk about associations to the topics before more defined questions were asked.

Implications for design and use

- What are the advantages and disadvantages with passive house requirements related to area and wall thickness? (light, space, etc.)
- How important is it to reduce the wall thickness? How much does a product with vacuum insulation need to reduce the wall thickness compared to traditional building methods, to be of interest for the market?
- Have you experienced any demands for products like this today? If so, in what contexts?

Costs

- How much do you think the market will be willing to pay for a product like this?
- Would a more expensive insulation product that reduces the wall thickness pay off in sites with high square meter prices?

Vulnerability

Vacuum packed insulation is vulnerable to puncture (but puncture of vacuum insulation in one Leca block has an insignificant effect on the insulation of the whole building).

- How will vulnerability to puncture be handled by workmen on a building site?
- What are your thoughts on training and understanding of the use of such products among various user groups (management, architects, and residents)?
- What lifespan/durability would you expect from a product like this?

Environmental characteristics

Products with vacuum packed insulation may be energy intensive to produce, depending on production methods. Presumably, the CO₂ emissions will be higher than for traditional equivalent products.

However, it is assumed that the environmental impact will balance out over time.

- Does this affect what you think about products with vacuum packed insulation? How?

2.4 Changes in the interview guide

During the interview process, the need for questions on future visions and alternative materials for vacuum insulation was obvious. The following questions were therefore added:

- What type of insulation do you think we have 50 years from now?
- What alternative materials would be interesting in combination with vacuum insulation?

It also turned out to be difficult for the informants to answer very detailed on costs and wall thickness. These questions were therefore asked more openly.

3. Results

3.1 Implications for design and use

Market for vacuum insulation

Most of the informants who are interviewed in this project believe in a future for vacuum insulation. Most of them consider themselves "technology optimists", like for instance this informant, working in a governmental organization, who argued; "50 years from now, there has to be better solutions than today! The researchers will come up with something." There are, however, diverse opinions on what type of product this should be, and what types of materials should be combined.

Most of the informants say that vacuum insulation in one or another form will be interesting and attractive for the market. This statement is often moderated by a reference to the costs, and on how effective these insulation products are.

Rehabilitation

Our informants express a pointed need for vacuum insulation in renovation projects, because there is less space for insulation both from the inside and the outside. Vacuum insulation in Leca blocks is not suitable for this purpose. Renovation projects demand a different product. The need for thin and effective insulation materials in renovation projects is however urgent, and may have a large market. One of the architects mentioned that he even had considered using insulation products from NASA, used on space rockets, to have insulation that is thin enough in special renovation projects.

Thinner insulation (like vacuum insulation) may inspire and encourage private house owners to renovate to improve the energy efficiency of their house or apartment. Solutions that make the walls thicker, make it less attractive to conduct energy efficient renovation projects. Thicker walls may take up valuable space, if put both on the inside and the outside of a wall. For example, in bathrooms that are small, extra insulation would probably stand in the way for universal design. Thinner and more effective insulation makes additional insulation in existing housing more attractive, but as long as the costs are too high, vacuum insulation is not an option. One informant mentioned an example with a 'balcony-accessed block', where additional insulation interfered with the necessary universal design width of the balcony access. In examples like that, thinner insulation would be of great value.

New buildings

Almost all informants state that in areas with high site costs, there will be a great market for vacuum insulation. The increasing demands on energy efficiency lead to the need for a product like this.

Effect and width

One of the informants said that products with vacuum insulation should at least insulate twice as much as traditional materials, to be of interest in the building market. An aim should be to reduce the wall thickness down to what is completely necessary in terms of relative strength in the wall, materials, and place for pipes and electrical installations: 20–25 cm in total. Another informant, who works with renovation of blocks of flats, argued that vacuum insulation should fit into existing walls in buildings from 1950–1980. Instead of putting on additional insulation, old insulation could be replaced by vacuum insulation, and have the required insulation effect of today. That means that vacuum insulation needs to be effective enough with ten centimeters width.

Materials

Some informants praise the combination of Leca blocks and vacuum insulation, and say that it sounds like a reasonable combination. Clay is a good and understandable form of protection of the vacuum panels. It is simple, and the building methods are well known. The product is relevant for use where

Leca blocks already would be considered as a natural choice, in foundation walls and brick buildings. However, as many of the informants point out, there are few brick buildings in Norway.

Many informants said that there is a great need for thinner insulation in wood constructions. But the challenges are many: Will it demand double walls to be well enough protected? Where in the wall should the vacuum panels be placed? How can vacuum insulation become safe and robust enough for wood constructions?

To make vacuum insulation useful for renovation projects, one of the informants suggested materials that are lighter and less voluminous than Leca blocks. For example vacuum insulation wrapped in light metal, for instance in the shape of 60x120 cm panels. There are however challenges with how to merge this type of elements, and how to avoid thermal bridges. Other informants were skeptical to the combination of different materials in the same product (see also 3.4 environmental impact). They asked if it is possible to use naked vacuum panels, and be able to choose what material to surround and protect them themselves.

Two of the informants from the housing sector asked for even more robust vacuum insulation products, with vacuum insulation in smaller cores, like a sponge with small vacuum bubbles (see the section about vulnerability).

Thick walls

Some informants claimed that the limit for wall thickness using traditional materials was reached, and expected that other insulation materials had to be introduced in the near future. They stressed that there has not been enough focus on the negative aspects with wall thickness in the passive house debate. Another informant said that the wall thickness is tolerable at the moment, and could not see that it needs to get thicker than it is today. He thought that it will remain this way, and that vacuum insulation is too risky. Some also argued that vacuum insulation seems too vulnerable, and they would wait for a more robust product. One informant stated that actions to achieve even more energy efficient buildings today have to be taken from more effective and environmental friendly energy sources; active actions instead of passive solutions (buildings producing energy).

Representatives from housing producers found thick walls as particularly challenging. In order to get enough daylight inside of the house, they found it difficult to place the windows correctly because of the thick walls. Some said that placing the windows at the farther end of the inner wall is a problem in relation to light and aesthetics. Thick walls are also challenging when it comes to use of new building materials. Others said that thick walls are a habit, and that people in general may get used to it.

Informants from trade organizations in the housing sector did not see any problems aesthetically with thick walls, referring to private living experiences. Some said that it may even be considered an advantage to have broad window frames to sit in, or place flowers or knick-knacks in. Their conclusion was therefore that thick walls may not be a problem in itself, but only in high cost sites.

3.2 Costs

Costs and savings

Many of the informants said that they believe in a market for an expensive vacuum insulation product. According to them there is a cost limit, but the advantages are obvious.

In cities where the site costs are high, there will be an extra need for vacuum insulation. Some of the informants stressed the need to see a calculation on how the use of vacuum insulation and thinner walls may compensate for space use. They point to the fact that an example of a calculation on this would be

a good way of promoting a product with vacuum insulation. Using the example of an office building, and how many square meters that may be rented out with and without the use of vacuum insulation would be interesting.

One architect also stressed that the economic savings for using vacuum insulation have to be seen according to the whole value chain of the building. The economic savings may also be related to less volume in transport, and other aspects in the value chain.

Building regulations

Two informants from pro-environment organizations mentioned that the challenges with thicker walls in passive houses in expensive areas, several times have been tried solved through requests for changes in building regulations. There seems to be good arguments to modify the demands for building density and the percent of built up area at the site for passive houses or other particularly environmental friendly buildings, to compensate for thicker walls. But this has not been favored by politicians. It is rather not a solution for the future, only for a period of transition.

Costs for insulation in renovation projects

In *renovation* projects in cities where the site costs are high, many argued that the market probably will be willing to pay extra for thinner and more effective insulation. Many of the informants also mentioned the fact that the costs of the product will diminish when the sales volume goes up.

3.3 Vulnerability

Skeptic

There is a general skepticism among the informants towards the vulnerability of a vacuum insulation product. One of the informants found the idea risky, especially since the durability of a product with vacuum insulation is unknown. Many of them said it would feel safer with a more robust product, especially because they did not know how long the insulation capacity will last. Some said that they would expect at least a 50 year lifetime for a product with vacuum insulation.

Training

The training of workers that handle the insulation products will be time consuming, and some said that a robust product would be preferred. At least, products that could be handled with conventional working methods would be easier to introduce.

One architect stressed the point that buildings have to be flexible. Buildings have to tolerate different users and a building has to bear mistakes. According to him this makes it difficult to choose vulnerable vacuum insulation.

Vacuum insulation bubbles?

Two of the informants asked about vacuum insulation in smaller cores, "Why cannot vacuum insulation products be more like a sponge?" They imagine a product with small vacuum bubbles. A product like that would be easier to handle, less vulnerable, and possible to cut without destroying all vacuum in one block.

3.4 Environmental characteristics

Environmental impact

The environmental impact of vacuum insulation was not a great concern among the informants, but they had a wait-and-see attitude to see a finished vacuum insulation product, and the exact environmental impact of it. Many of the informants pointed to the fact that it is energy consuming to produce traditional

insulation too, and that the different insulation products have to be compared, and all relevant aspects in the whole production chain has to be evaluated.

However, according to X, the BREEAM system, the leading method for assessment of sustainable buildings, increases the focus on environmental impact of building materials. It would not be very proactive to focus research on a product that is "out dated" because of its environmental impact. One of the informants from a pro-environmental organization said that the environmental impact should be in balance in at least 20 years, to be of interest for the building market.

Pre-separation at source

Many of the informants were skeptical towards the combination of different materials in the same product, and said that there has to be a clear plan for pre-separation at source. The building industry wants cleaner products, and it is therefore strange that researchers focus on developing products with combined materials. Some informants asked if it is possible to have naked vacuum panels, and be able to handle them themselves, be able to choose how to protect them, and what materials that may be wrapped around the panels.

However, one of the other informants said that the vacuum panels have to be integrated in finished products to be realistic to use in building projects. Otherwise, the potential in housing construction will be low.

Health

Two of the informants from the trade organizations in the housing sector talked about health aspects in relation to insulation. In their experience, insulation that is used the most frequently in the building market today may have negative health effects, and people get allergic reactions. They therefore ask for more natural insulation materials. One of these informants pointed to the fact that health should be more in focus when developing new insulation materials, and maybe vacuum insulation in clay blocks or with other materials is a better product in that way? Future vacuum insulation products have to be free of harmful gasses and chemicals.

4. Discussion and conclusions

4.1 Discussion

Difficult to quantify

It turned out to be difficult for the informants to quantify what costs are tolerable (as this depends on the specific situation and costs of the building site). It also turned out to be difficult for the informants to quantify how many centimeters the product has to diminish the wall thickness of today, to be of interest for the building industry. A dream situation for renovation: Vacuum insulation should be so thin and effective that old insulation in walls from 1950–1980 may be exchanged with new, and fulfill today's requirements without expanding the wall.

A clear request is to use *calculation examples* on concrete buildings, to show the building industry the possible savings the use of vacuum insulation would give. These examples should show the difference in price related to square meter costs. This is a good advice for promoting vacuum insulation products, and should be followed up.

A need for material flexibility

Many of the informants found the combination of Leca blocks and vacuum insulation a good combination. But there were also other wishes for material use: some wanted vacuum insulation in combination with wood or metal, and others pointed to the fact that products with small vacuum "bubbles" sounded more robust. Some wanted naked vacuum panels to handle of their own. To make vacuum insulation a central building product in the future, a great degree of material flexibility will be an important demand.

The answers reflect that the knowledge about the difficulties in developing these types of products is uneven. At the same time, the requests may be of inspiration for the researchers who work with these products. It is especially interesting that some of the informants have belief in "vacuum bubbles". Researchers – also within the ZEB centre – have been working with this type of vacuum insulation for some years (Grynning et al., 2009).

Wall thickness

Most of the informants said that the wall thickness has reached its limit in passive houses. However, the opinions about the aesthetic quality of thick walls are not unanimous. Some find it very problematic; others find thick walls aesthetically nice. It is especially housing contractors that experienced the wall thickness as a problem. Most of the other informants did not have anything against thick walls in particular.

This indicates that it is especially in the cities where the sites costs are high, that thick walls are problematic. Thick walls are not necessarily seen as a problem in the building industry in general. This may reflect the situation of today, but when even more demanding regulations of energy efficiency are introduced, the wall thickness may be experienced as more problematic.

Vulnerability

The vulnerability of the product was an essential topic for the informants, even if the producer of the Leca block vip, Weber, did not see it as a major problem. The informants' doubt about the robustness of the vacuum insulation may be a result of the focus on the theme in the interview guide. Only when they were asked about it, they started to doubt the product.

There seemed to be a need among the informants to receive more information about the robustness of the product, and to be assured that a certain degree of vulnerability of the product is tolerable. This

indicates that when introducing a product with vacuum insulation to the market, how to present the risks about puncturing is an important aspect to consider.

Environmental impact

The opinions on the meaning of the environmental impact of vacuum insulation were diverse. Some were not concerned about it and stated that all insulation products of today are energy demanding to produce. They did not see how vacuum insulation might differ from the other products. Other informants, especially informants who worked with sustainable buildings, were more concerned about the environmental characteristics of the product. However, when introducing a vacuum insulation product, it is important to make a clear plan for pre-separation at source. A focus on health aspects was also asked for.

4.2 Conclusions

- Vacuum insulation in one or another form will be interesting and attractive for the market.
- Some find thick walls problematic, others find them nice and practical. The opinions are diverse, which should be addressed in the promotion of the products.
- Vacuum insulation may be especially important for renovation projects and new buildings where the site costs are high.
- In order to be attractive for renovation projects, a product that is applicable to existing constructions has to be developed. There is a great need for renovation of the existing building mass, so the market share of a thin insulation product for renovation may be even higher than for new buildings.
- If the price of vacuum insulation decreases over time, there may be a market for thinner insulation among private house owners rehabilitating their dwellings to more energy efficient constructions.
- To make vacuum insulation a central building product for the future, a great degree of material flexibility will be important. There are diverse opinions on what types of materials that should be combined. Vacuum insulation in clay blocks seems like a reasonable combination to most of the informants. Vacuum insulation in thinner and lighter materials than clay blocks, especially vacuum insulation for wood constructions is asked for. Also, more robust vacuum insulation in "bubbles" is wanted.
- For future promotion of a product with vacuum insulation, it is important to convince the market that it is robust enough, and show calculation examples on how the product may be more income-producing when used where site prices are high. Advantages in the whole value-chain may be important to explain.
- The environmental impact of vacuum insulation matters to some, others say that all insulation types are energy consuming to produce, and they cannot see why vacuum insulation should be any worse over time. A clear plan for pre-separation at source is asked for. Some asks for a special focus on health and avoiding harmful gases and chemicals when developing new insulation materials.

4.3 Recommendations for future research

- Vacuum insulation products for renovation.
- Different types of vacuum insulation (bubbles, sponges) / different types of material in combination with vacuum panels.
- Documentation of economic gains when using vacuum insulation in buildings where site prices are high.
- Health effects of vacuum insulation.

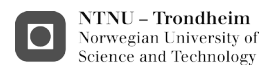
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The Research Centre on Zero emission Buildings (ZEB)

The main objective of ZEB is to develop competitive products and solutions for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition. The Centre will encompass both residential and commercial buildings, as well as public buildings.



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www.dibk.no

DuPont

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NorDan AS

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