

PRECAST MASONRY WALL PANELS: STATE OF THE ART

Kristýna Richterová, *

Katedra betonových a zděných konstrukcí, Fakulta stavební,
České vysoké učení technické v Praze, Thákurova 7/2077, 166 29 Praha 6, Česká republika.
kristyna.richterova@fsv.cvut.cz

ABSTRAKT

Následující příspěvek se zabývá prefabrikací zdiva, konkrétně historickými a současnými prefabrikovanými stěnovými panely ze zdiva a ověřením proveditelnosti nového systému prefabrikovaných zděných stěnových panelů z produktů dostupných převážně na českém trhu. Článek shrnuje především získané poznatky o současných systémech prefabrikace zdiva u zahraničních firem a informuje o vzniku diplomové práce s názvem „Prefabrikované stěnové panely ze zdiva“, která se zabývala návrhem a posouzením proveditelnosti obdobného systému v českých podmínkách. Závěr článku se věnuje diskusi nad možnými problémy a riziky, které souvisejí s konceptem prefabrikace zdiva a dává podnět k tématům pro další výzkum, který bude součástí disertační práce autorky článku.

KLÍČOVÁ SLOVA

prefabrikace • zdivo • panel • pojivo • manipulace

ABSTRACT

The following paper deals with precast production of masonry, specifically with the past and present types of masonry precast panels. There is also assessed feasibility of a new masonry precast panel system made mostly of available Czech products. This article summarizes the gained information about the present system of precast production of masonry in foreign companies and informs about the master thesis named „Precast masonry wall panels“, which deals with the design and feasibility assessment of similar system in Czech conditions. Conclusion of the article proposes a discussion of possible problems and risks, which are related to the concept of precast production of masonry and it also initiates topics for the next research. Consequential research will be a part of author's dissertation thesis.

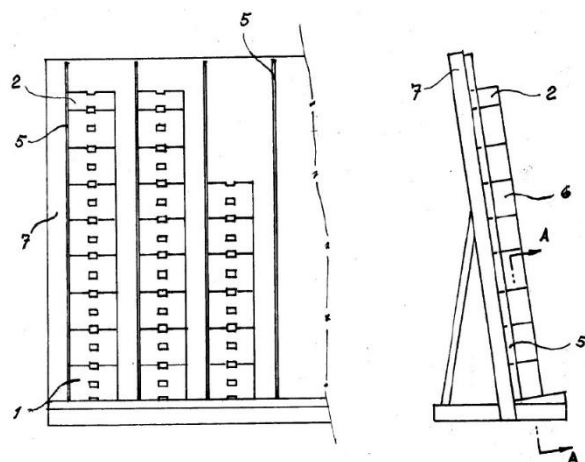
KEYWORDS

Precast production • masonry • panel • adhesive • manipulation

1. PREFACE

Today's trend is the construction of structures in the shortest possible time, using suitable and efficient construction methods in compliance with high quality implementation. The construction of precast buildings made of reinforced concrete and timber is therefore more and more popular. The effort to produce precast masonry wall panels in the Czech Republic is obvious from historical documents and patents from the second half the 20th century. Insufficient technological and material progress caused unsuccess in the precast masonry production branch at that time. The construction from precast masonry wall panels became actual mainly in Austria, Germany or Belgium at the beginning of the 21st century.

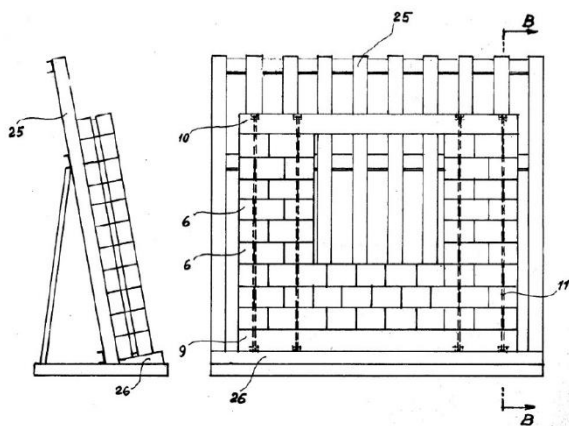
From granted patents in the 80s of the 20th century (for example the patent 219013) (Vranka et al. 1985), it is obvious that the production process and produced precast parts correspond with the present innovative methods at foreign companies. However, great progress has been made in the quality of used materials, mechanization of production process and in transport of precast parts to the construction site. Therefore, the implementation of construction from precast parts is the next step in the development of construction industry in the Czech Republic and it is also the reason for competitiveness with foreign companies, but mainly with construction of buildings from rival materials.



1) ceramic bricks; 2) additional bricks; 5) rib;
6) rod element; 7) pad

Figure 1: The patent 219013 – The first phase of production of a ceramic wall panel (Vranka et al. 1984)

* Supervisor: Petr Bílý, Ph.D.



6) rod element; 9) lower reinforcing beam; 10) upper reinforcing beam; 11) manipulative rod; 25) inclined grate pad; 26) platform

Figure 2: The patent 219013 – The made ceramic wall panel (Vranka et al. 1984)

Within the master thesis named „Precast masonry wall panels“ (Richterová 2021) there was researched, whether the implementation of the concept of construction of buildings from precast masonry wall panels could be introduced in the Czech Republic. This paper deals with the obtained information from the final thesis and it also considers the issues of the concept of precast masonry production.

2. METHODS OF PRECAST MASONRY PRODUCTION ACCORDING TO PRESENT SYSTEMS

At first, the information about already known systems of foreign companies was processed to approach the issue of precast masonry production and for search inspiration. Foreign companies offering precast masonry wall panels construction and other precast parts in their portfolio are Austrian company named Redbloccsystems® and German companies named Rimatem® and Rötzer® Ziegel Element Haus. Available information about these companies confirm, that the great progress has been made in precast production of masonry during last few years. Named companies produce precast masonry wall panels in different way, but main characteristics and thoughts of the concept are the same – automatic production, high quality and production accuracy of panels owing to production machine, reduced construction time, production independence of weather conditions, reduction of the number of necessary employees in production even during assembly in the construction site.

2.1. Redbloccsystems®

Redbloccsystems® was developed in Austria at the beginning of the 21st century. The system combines advantages of masonry

structure from the point of view of quality of living, sustainability, thermal and sound insulation with increased construction productivity, which is typical for precast buildings.

Interested parties can get a license of Redbloccsystems®, which is offered by the parent company. The license includes turnkey automatic production lines for the precast production of wall elements, software for precast production, system design, assembly of the system, training course for employees, putting the system into operation and also necessary documentation (Redbloccsystems®/Produktionslinien ©n.d.).

Production of precast masonry wall panels begins with preparation and processing of technical data using the new precast software – die Elementierungssoftware NEMETSCHKE. Then the computation of masonry elements is solved for given construction in the software MBS. Precast production is under way on the fully- and semi-automatic production lines in vertical position. The method of production depends on the concept of the company. Precast elements are made with great accuracy and quality thanks to automatic production system and they are transported with already made groves for wiring, with skew edges or construction holes (Redbloccsystems® ©2018, Brückner 2017, Redbloccsystems®: Die Zukunft am Bau hat schon begonnen ©n.d.).

Table 1: General technical data Redbloccsystems® (Redbloccsystems®/Produktionslinien ©n.d.)

Basic material:	ceramic bricks, aerated concrete, silica blocks etc.
Production time:	1 hour
Productivity:	150 000 – 200 000 m ² per year
Thicknesses of wall elements:	from 10 to 51 cm
Max possible height of wall:	3 500 mm
Max possible length of wall:	5 000 – 8 000 mm
Necessary number of employees:	5 – 6 employees
Return of investment:	app. 3 – 5 years
Necessary building dimensions:	app. 60x20x6 m (fully automated)
	app. 30x18x6 m (semi-automated)
Production per shift:	350 m ² (fully automated)
	120 m ² (semi-automated)



* Supervisor: Petr Bílý, Ph.D.



Figure 3: The production of Redbloccystems® panels (Redbloccystems®: Die Zukunft am Bau hat schon begonnen ©n.d., Redbloc®/Produktionsschritte ©n.d., Redbloccystems®/Lizenznehmer ©n.d.)

The company's know-how is the named software for data processing from project documentation, on the one hand, but also the innovative 2K-PUR adhesive. It is fast-curing two-component adhesive made from an adhesive component (ISA PUR 2607) and a hardener (HÄRTER 414), which is cured after only one day. Both components are mixed in ratio of 100/100 [g/g] with a processing time of 55 seconds at a temperature of 15–25 °C (Technische Goedkeuring ATG 2019).

Table 2: Component A properties – adhesive component (Technische Goedkeuring ATG 2019)

Component properties A – ISA PUR 2607		
Hydroxyl number	[(KOH)/g]	275
Viscosity	[mPa·s]	700
Density	[g/cm ³]	1,1
Colour	[-]	milk
Storability - unopened package (15 °C – 25 °C)	[month]	12

Table 3: Component B properties – hardener (Technische Goedkeuring ATG 2019)

Component properties B – HÄRTER 414		
Isocyanate content	[%NCO]	31
Viscosity	[mPa·s]	200
Density	[g/cm ³]	1,2
Colour	[-]	dark brown
Storability - unopened package (15 °C – 25 °C)	[month]	12

The precast panels are transported by heavy trucks to the construction site, where the crane is also set up. Then the precast

panels are placed on a prepared ground plan of baseplate / of ceiling construction according to the assembly plan. Precast masonry wall panels are placed in fresh mortar bed on the base levelling tiles. Fresh mortar bed must meet the prescribed requirements and the precast masonry wall panels are temporarily fixed by struts, which ensure their vertical position. Assembly joints between precast masonry wall panels are filled by PU glue / injection mortar on the inner and outer side. The 20-centimetre-wide fiberglass reinforcement fabric is also placed on the inside of the joint (Technische Goedkeuring ATG 2019, Redbloc®/Montageschritte ©n.d.).



Figure 4: The preparation of construction site according to the assembly plan (Redbloccystems® ©2018, Redbloc®/Montageschritte ©n.d.)

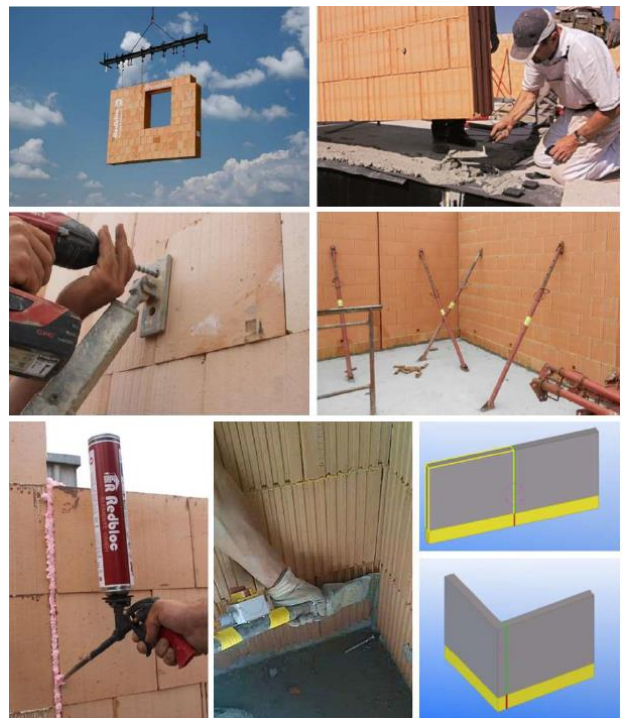


Figure 5: The assembly of Redbloc® panels on the construction site (Redbloccystems® ©2018, Prefaxis 2019, Redbloc®/Montageschritte ©n.d.)

2.2. Rimatem®

The German company named Rimatem® has a very similar system of precast masonry to the named Redbloccystems® - see

* Supervisor: Petr Bílý, Ph.D.

above. The company also offers a fully automatic or semi-automatic production plant for precast masonry structures without material restriction of masonry elements. Semi-automatic production lines are comprised of a manufacturing crane, manufacturing platform sliding in the vertical direction and of a silo. The manufacturing crane facilitates the laying of masonry elements to the operator, the manufacturing platform provides an ergonomic position of the operator incessantly during the precast panel production and the silo is used for automatic application of masonry mortar on individual masonry rows. Manufactured precast panel can be produced with a height of 4 meters and a length of up to 13 meters on semi-automatic line. Masonry elements for precast production panels can be 110–500 millimetres thick. Fully automatic production line is advisable to choose for the large production plants, where complete production is automatically controlled by computer (Rimatem®/About us ©n.d., Rimatem®/sakha-prom ©n.d.).



Figure 6: Semi-automatic production line Rimatem® (Rimatem®/Semi-automatic HA IV ©n.d.)



Figure 7: Fully automatic production line Rimatem® (Rimatem®/Fully automatic VA II ©n.d.)

The company named Rimatem® developed ingenious solution for transport and manipulation with precast masonry wall panels. The Rimatem Vario-traverses were made specially for manipulation and the transport containers were made for storage and transport to the construction site (Rimatem®/Systems solutions for transportation and assembly ©n.d.). Assembly of precast masonry wall panel is the same as at the company named

Redblocksystems®, it differs only in the used lifting components – the Vario-traverse are lashed by steel straps instead of using lifting bars.



Figure 8: The made Rimatem® panels with Vario-traverse on the transport container (Rimatem®/sakha-prom ©n.d.)

2.3. Rötzer® Ziegel Element Haus

The company named RZEH® comes from Germany too, but her production concept of precast masonry wall panels is very different in comparison with Redblocksystems® or Rimatem®.

The precast masonry wall panels production takes place in horizontal position. At first the wall shape is drawn on working desk of production line. The layout includes construction holes, position of electric devices or HVAC wirings. After that the masonry elements are automatically placed on the ground plan and the formwork, electric devices and pipeline are placed. The steel bars are deployed between rows of masonry elements to ensure stability of precast panels during manipulation. Then the prepared and boarded up panel is poured with mortar. After that the panel is transferred to kiln for 48 hours. At last the panel is stripped, lifted to a vertical position and plastered. The panels are manufactured this way in a thickness of up to 280 mm, a height of 3250 mm and a maximum length of 7000 mm. The transport of precast panels and their assembly on the construction site is the same with foregoing systems (Rötzer® Ziegel Element Haus/Ziegel-Element Haus ©n.d., RZEH Beitrag AbenteuerLeben 2016, Rötzer® Ziegel Element Haus/Ziegelwände für außen und innen ©n.d.).



* Supervisor: Petr Bílý, Ph.D.



Figure 9: *The production of precast wall panel RZEH® (Rötzer® Ziegel Element Haus/Das Werk/Fertigung ©n.d.)*

3. GAINED KNOWLEDGE AND RESULTS

It is obvious from the obtained information that the concept of building of precast masonry panels is founded on suitable adhesive and suitably designed lifting system. The adhesive must be sufficiently hardened in a short time and the lifting system is important for manipulation with precast panels on the construction site.

The gained knowledge about the past and present systems are great sources for development of our own precast masonry system in the Czech Republic. Within the master thesis under the patronage of the company HELUZ, the chosen adhesives were put to the adhesion test and shear test according to ČSN EN 1052-3. After that the lifting system was designed for manipulation with precast masonry wall panels. At last the precast panel was put to the lift test. It is not possible to publish the results due to delicacy of data from the external company. It can only be pronounced, that the designed concept passed all the tests successfully and so its feasibility was confirmed (Richterová 2021).

4. DISCUSSION ABOUT THE CONCEPT OF PRECAST MASONRY

The results obtained from the performed tests initiate the continuation of the precast masonry research. Before implementation of the concept of precast masonry wall panels in building construction, possible problems and risks, which relate to the concept, must be considered.

At first the correct design of building is important for precast masonry wall panels production. The masonry structures are usually designed in a height and length module of 250 millimeters and this should be always adhered – especially for precast buildings. During the construction of precast masonry wall panels buildings it is also necessary to pay attention to buildings with corner windows, large construction holes and with the skew edges. On the grounds of this, it is important to design the precast production method and assembly on the

construction site suitably – as the case may be finishing a part of the construction by traditional method.

The solution of lintels is a question too. The lintels of the present companies are solved by using the accessible precast lintels, monolithic reinforced concrete lintels and own lintel production. Precast lintel is installed in the production shed, the monolithic reinforced concrete lintel is made directly on the construction site and the own produced lintel is made of the same materials as the remaining construction in the production shed.

The solution of assembling joints between precast wall panels is the pivotal question. The inspiration can be found in the present well-established companies, which apply only PU adhesive or injection mortar in the assembling joint and install the reinforcement fabric on the inside of the joint. However, the precast panels are not interconnected in this way and it is a question of how the building will behave in relation to applied load from the long-term point of view. The implementation of mechanical joint between precast panels should be the solution of own patented connection system, which must be first produced and certified.

The next possible risks of precast masonry wall panels concept are:

- The insufficient production capacity of masonry elements for precast masonry production.
- The necessary initial investment in production line, procuring of storage spaces, training of employees and other necessary materials for production with the risk of failure.
- Transport of precast masonry wall panels by the heavy truck and the necessary presence of the crane on the construction site. The question is: How much are the transport by heavy truck on roads and the need of crane for precast panels manipulation restrictive?
- The brittleness of ceramic masonry elements – It could cause damage of a part of precast panel before its assembly on the construction site. The damage of the panels would lead to delay of construction and other complication for the ordering party and contractor.

Therefore, it is important to consider all the possible risks and problems and come up with a reasonable and functional solution, so that the introduction of the concept of buildings construction of precast masonry panels would not be accompanied by any problems on the Czech market and the concept would be fully functional (Richterová 2021).

5. CONCLUSION

This article introduces the present systems of precast masonry wall panels, which were sources for the practical part of the master thesis of article's author. The foreign companies Redbloccsystems®, Rimatem® and RZEH®, which have the elaborated system of production, transport and assembly of precast masonry on the construction site, were introduced. The adhesives for the lift test were selected based on gained results of adhesion and

* Supervisor: Petr Bílý, Ph.D.

shear test of several adhesives. The selected adhesives and designed lifting system succeeded in the test, but there is a space for search for better alternatives and solution of problems related to the concept of precast masonry.

Within the dissertation thesis the topic will be extended by the issues of spatial rigidity of precast masonry load-bearing system, the rigidity of precast joints, the fire resistance of precast masonry structures, the assesment of selected joints, the design of suitable dimensions and shape of bricks / precast structures, the possible methods of production mechanization and the economic evaluation of the definite concept.

ACKNOWLEDGEMENT

The acknowledgement belongs to Petr Bílý, Ph.D., who was the supervisor of my master thesis named „Precast masonry wall panels” and to the company HELUZ, which shielded the full thesis. The financial support of the internal CTU grant SGS19/149/OHK1/3T/11 is gratefully acknowledged.

Reference

- RICHTEROVÁ, Kristýna, 2021. Prefabrikované stěnové panely ze zdiva. Praha. Diplomová práce. České vysoké učení technické v Praze. Vedoucí práce Ing. Petr Bílý, Ph.D.
- NEUVEDEN podle zákona 84/1972 Sb., Československo, 1985. Keramický stěnový dílec tvořený zdicími, zejména lehčenými tvarovkami. Průvodci: Ludvík VRANKA, Evžen BRUNNER, Petr PASEKA a Petr MUSIL. Československá socialistická republika. Patentovaný spis ČSSR 219013 B1. 15.06.
- NEUVEDEN podle zákona 84/1972 Sb., Československo, 1984. Způsob výroby keramického stěnového dílce. Průvodci: Ludvík VRANKA, Evžen BRUNNER a Petr Musil. Československá socialistická republika. Patentovaný spis ČSSR 224658 B1. 01.10.
- Redblocsistemas®: *Produktionslinien* [online]. [Cit. 12.05.2020]. Dostupné z: <https://www.redblocsistemas.com/produktionslinien/>
- Redblocsistemas®: *Was ist redbloc®?* [online]. 2018 [Cit. 12.05.2020]. Dostupné z: https://www.redblocsistemas.com/fileadmin/user_upload/2018_What_is_redbloc_de.pdf
- BRÜCKNER, H. 2017. Ziegelfertigteile - Die Zukunft des Ziegels. *TECHNOLOGIE-FORUM* [online]. 161-163 [Cit. 12.05.2020]. Dostupné z: https://www.redblocsystems.com/fileadmin/user_upload/Keramische_Zeitschrift_06_2017_TF_Br%C3%BCckner_pek.pdf
- REDBLOCSYSTEMS®, Die Zukunft am Bau hat schon begonnen [online]. [Cit. 12.05.2020]. Dostupné z:

<https://www.redblocsystems.com/fileadmin/content/engineering/redblocsistemas/downloads/imagefolderredblocsistemas/redblocsistemas-folder-de-web.pdf>

- Redbloc®: *Produktionsschritte* [online]. [Cit. 12.05.2020]. Dostupné z: <https://www.redbloc.at/produktionmontage/produktionsschritte/>
- In: *Redblocsistemas®: Lizenznehmer* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.redblocsystems.com/lizenznehmer/>
- Technische Goedkeuring ATG. In: *Prefaxis* [online]. 10.12.2019. 1-11 [Cit. 12.05.2020]. Dostupné z: http://www.verbo.eu/media/13033/atg2968_191210_nl.pdf
- Redbloc®: *Montageschritte* [online]. [Cit. 12.05.2020]. Dostupné z: <https://www.redblocelemente.de/montage/montageschritte/index.html>
- Montagehandleiding keramische muren. In: *Prefaxis* [online] 2019. [Cit. 12.05.2020]. Dostupné z: http://www.verbo.eu/media/13081/montagehandleiding_verbo_muren_vb7_nl_06_2016_logogewijzigd_bert.pdf
- Rimatem®: *About us* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.rimatem.com/en/about-us/>
- Rimatem®: *Технология готовых стен* [online]. [Cit. 29.12.2020]. Dostupné z: https://sakhaprom.by/images/upload/Construction_catalogue.pdf
- Rimatem®: *SEMI AUTOMATIC HA IV* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.rimatem.com/en/semi-automatic-ha-iv/>
- Rimatem®: *FULLY AUTOMATIC VA II* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.rimatem.com/en/fully-automatic-va-ii/>
- Rimatem®: *SYSTEMS SOLUTIONS FOR TRANSPORTATION AND ASSEMBLY* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.rimatem.com/en/components-accessories/>
- Rötzer® *Ziegel Element Haus: Ziegel-Element-Werk* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.roetzerziegelhaus.de/ziegel-element-werk-hochmodernanlage-zur-ziegelproduktion.html>
- RZEH Beitrag AbenteuerLeben. In: *Youtube* [online]. 2016 [Cit. 29.12.2020]. Dostupné z: <https://www.youtube.com/watch?v=CBZYwI3BJ9E&t=363s>
- Rötzer® *Ziegel Elemente: Ziegelwände für außen und innen* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.roetzerwerk.de/ziegelw%C3%A4nde.html>
- Rötzer® *Ziegel Elemente: Das Werk/Fertigung* [online]. [Cit. 29.12.2020]. Dostupné z: <https://www.roetzerwerk.de/das-werk-fertigung.html>

* Supervisor: Petr Bílý, Ph.D.