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Obsah čísla:

MEASURING OF THE ECONOMIC CYCLE ON THE LABOUR MARKET IN THE CZECH CONSTRUCTION SECTOR BY THE MEANS OF NAIRU

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ABSTRACT

The paper is concerned with the economic cycle on the labour market in the whole national economy and in the construction sector of the Czech Republic, working with NAIRU. This variable is estimated with the use of the consumer price index and the construction work price index. By comparing the obtained NAIRU values with the real unemployment rates we determine the phase of the economic cycle. We verify the localised phases of the cycle on the labour market in the national economy and in the construction sector with the development of the real unemployment rate and the added value. Thanks to this approach we get the insight into the development of unstable periods on the labour market.

KEYWORDS

Economic cycle, Phillips curve, NAIRU, HP filter, Kalman filter, Stochastic trend, Unemployment gap

INTRODUCTION

The present article expands on and extends analyses published in past years [1] and [2] in this journal. The initially studied time interval from the 1st quarter of 1994 to the 2nd quarter of 2007 is extended by this paper to the 4th quarter of 2012. The analysis thus covers not only the period in which the Czech economy was hit by the financial and economic recession, but now also the period which immediately followed. At first we used two variants of price indicators (deflators and price indexes) and subsequently we applied only deflators. Now we use price indexes – at the level of the national economy it is the consumer price index, at the level of the construction sector it is the construction work price index. As for the previously used methods for the NAIRU estimation, we continue in working with the Hodrick-Prescott filter (hereinafter the HP filter) and the Kalman filter and we supplement them by the method of the Stochastic trend.

In the theoretical framework we build on the already presented theoretical approaches and we apply findings of economists that analyse economy from the perspective of sectors [3], [4], [5], [6], [7], [8]. These are sectors that have forces which dynamize the economy. In our previous analyses the objectives of the researches were volatility in the development of NAIRU and the economic cycle, confirmation of substitution between the unemployment rate and inflation, indication of the unstable period in the development at the national economy level and in selected sectors, finding reasons of the creation of instability and ways of its manifestation. Now we make verification of the development of NAIRU and the economic cycle on the labour market, using data from the real economy. We also strive to determine the most suitable method for estimating NAIRU and phases of the economic cycle under the conditions of the national economy and in the construction sector in the Czech Republic.

The basis for understanding and mapping the relation between unemployment, inflation and economic performance are two theoretical concepts: the Phillips curve (hereinafter PC) and the non-accelerating inflation rate of unemployment (hereinafter NAIRU). A. W. Phillips is generally regarded as the founder of the modern version of the PC. [9] He statistically confirmed that there is a substitution relation between the rate of change in nominal wages and the rate of change of unemployment and that economic policy makers can make use of them. One of the followers of the PC concept is J. Tobin. [10] He defines NAIRU as a long-time unemployment rate, which reflects the result of the macroeconomic balancing of pressures on the inflation growth from markets with excess demand and pressures on the inflation decline from markets with excess supply. To find out which phase of the economic cycle the labour market belongs to in the observed period, we have to subtract the defined NAIRU from the real unemployment rate. When the real unemployment rate is lower than NAIRU, we talk about a positive unemployment gap. In the opposite case it is a negative unemployment gap. The derived gap, in other words the negative unemployment gap, provides information about the presence of inflation or deflation pressures coming from the labour market.

1. DEVELOPMENT OF NAIRU AND THE ECONOMIC CYCLE IN THE WHOLE NATIONAL ECONOMY AND IN THE CONSTRUCTION SECTOR WITH THE USE OF PRICE INDEXES

We used the consumer price index and the construction work price index to obtain the values of the invisible variable NAIRU. The time series of price indexes are modified in order to reflect the adaptive forming of the expectation (year-on-year change in time t - year-on-year change in time t-1). To describe the development on the labour market we use the registered unemployment rate according to the Ministry of Labour and Social Affairs in % and our own specific unemployment rate in the construction sector in %. [11] Other explanatory variables are the registered unemployment rate without a delay and the specific unemployment rate in the construction sector with a delay in %, year-on-year changes of the exchange rate in % and year-on-year changes in import prices in %. Unemployment rates have been seasonally adjusted with the multiplicative moving average. All the data used was tested by the Augmented Dickey–Fuller test for stationarity.

1.2. Application of the HP filter for the NAIRU estimation and conclusions for the development of the economic cycle

The first method applied to estimate the time-varying NAIRU is the HP filter.

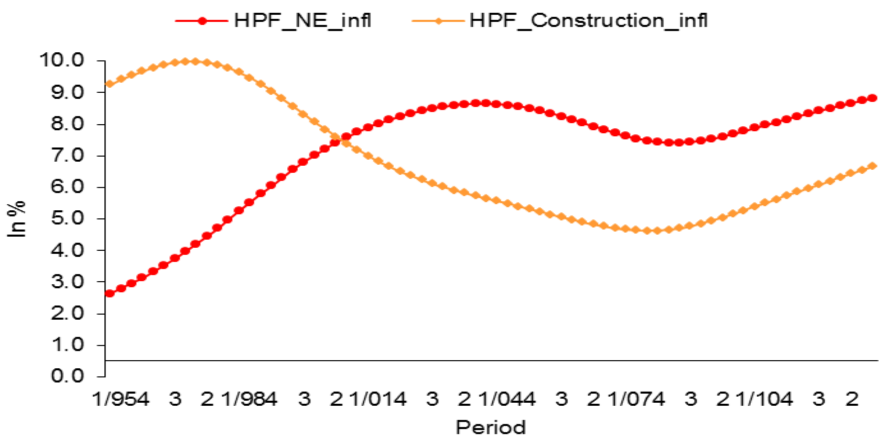

Fig. 1: Development of NAIRU according to the HP filter in the national economy and in the construction sector (Source: Our own calculation based on data from the Ministry of Labour and Social Affairs and the Czech Statistical Office)

From the analysis of results obtained by the **HP filter** follows that:

1) In the **whole national economy** in the Czech Republic NAIRU estimated by the HP filter ranged in the interval of 2.6 to 8.8% and in the **construction sector** in the interval of 4.6 to 10.0%.

2) In the **whole national economy** the NAIRU values mostly copied the real unemployment rate very closely . The interval in the **construction sector** was wider than in the whole national economy.

3) The longer-term and larger unemployment gap in the period from the 1st quarter of 1999 to the 1st quarter of 2000 was still a result of at that time ongoing transformation of the **Czech economy**. Thus identified recession on the labour market corresponded to the development of the real published unemployment rate and the GDP at constant prices. In the **construction sector**, this systemic and political change was apparent in the period from the 1st quarter of 1996 (3 years before the development of the whole NE) to the 4th quarter (3 years earlier than in the whole NE).

4) A large positive gap and a boom phase in the **Czech Republic** were found in the period from the 2nd quarter of 2007 to the 4th quarter of 2008. A positive gap and the boom phase in the **construction sector** were found in the period from the 2nd quarter of 2005 to the 4th quarter of 2008, which is 2 years earlier than in the whole national economy.

5) The influence of another recession on the labour market in the **Czech Republic** can be identified in the period from the 2nd quarter of 2009 and it lasted until the 1st quarter of 2011. Its influence in the **construction sector** became apparent in the 1st quarter of 2009 (just as in the whole NE) and lasted until the 4th quarter of 2012 (7 quarters longer than in the whole NE)

6) In the period from the 3rd quarter of 2001 to the 3rd quarter of 2012 there was a phase of shallow boom detected in the **Czech Republic**.

1.2 Application of the Kalman filter for the NAIRU estimation and conclusions for the development of the economic cycle

We used the Kalman filter as another method for estimation of the phases of the cycle. The Kalman filter uses the year-on-year change of the consumer price index and of the construction work price index in % as a dependant variable. The fixed regressors registered the unemployment rate in the NE (without a delay in %) and the specific unemployment rate in the construction sector (with a delay in %), year-on-year changes of the exchange rate in % with a delay (in the construction sector this variable wasn't significant) and year-on-year changes of import prices in % without a delay (in the construction sector this variable wasn't statistically significant).

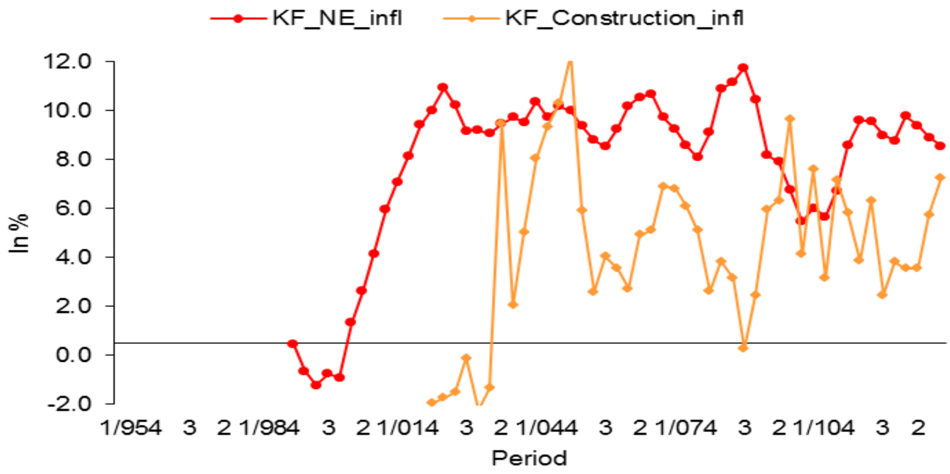

Fig. 2: NAIRU according to the Kalman filter in NE and in the construction sector (Source: Our own calculation based on data from the Ministry of Labour and Social Affairs, the Czech Statistical Office and the Czech National Bank)

From the analysis of results obtained by the **Kalman filter** follows that:

1) Values of NAIRU obtained with higher smoothing than usual ranged relatively significantly far around the real unemployment rate. In the **whole national economy** NAIRU reached values between **-**1.2 and +11.8% and in the **construction sector** between **-**2.3 and +12.3%.

2) In the **Czech economy** the model with smoothing of 0.6 reacted to the process of transformation by negative and unrealistically low positive values of NAIRU. In the period from the 1st quarter of 1999 to the 1st quarter of 2000 the estimated NAIRU was negative and until the 3rd quarter of 2000 it was positive with values not corresponding with the development of the real unemployment rate. In the **construction sector**, negative and low positive values of NAIRU occurred in the period from the 4th quarter of 2001 to the 1st quarter of 2003. The **phase of recession** on the labour market **generated** by the model was in accordance with the development of real variables.

3) The reason for the creation of high positive gaps (ca. 5 p.p.) in the **whole national economy** in the period from the 4th quarter of 2007 to the 4th quarter of 2008 was the inability of the model to reflect the last significant improvement of the situation on the labour market into the NAIRU values. In the **construction sector** there were found positive gaps of ca. 2.0 p.p. in the period from the 3rd quarter of 2006 to the 3rd quarter of 2007. The beginning of this period precedes the development in the whole national economy (4th quarter of 2007). By contrast, the end of this phase lags behind the whole national

economy (4th quarter of 2008). This short boom phase on the labour market is in accordance with the development of the real economy.

4) The influence of the recession on the labour market in the **Czech Republic** started to be apparent in the 3rd quarter of 2009 and lasted until the 4th quarter of 2010 and it corresponded with the real economy development. In the **construction sector** the influence of recession showed from the 4th quarter of 2007 to the 3rd quarter of 2012. The beginning of the recession in the construction sector preceded the development in the whole national economy. Its effect in the whole national economy ended in the 4th quarter of 2010, which is much sooner than in the construction sector.

5) In the **whole national sector** we can trace the boom phase from the 1st quarter of 2011 to the 3rd quarter of 2012. Gradual depletion of this gap resulted in the return of the **recession phase** to the labour market in the 4th quarter of 2012. In the **construction sector** this **phase** was traced only in the 4th quarter of 2012 (the average positive gap was 0.4 p.p.), which was in contradiction with the development of real data (the specific unemployment rate increased annually by 2.0 p.p. and the added value decreased annually by 5.4%).

1.3 Application of the Stochastic trend for the NAIRU estimation and conclusions for the development of the economic cycle

In this model the dependant variable was also the consumer price index and the construction work price index (year-on-year changes in %). Explanatory variables were year-on-year changes of the consumer price index at the level of the whole national economy and of the construction work price index with various delays in %, unemployment rates with delays in %, year-on-year changes of the exchange rate with a delay (beyond the level of the whole national economy) and year-on-year changes in import prices in % with delays (apart from the whole national economy).

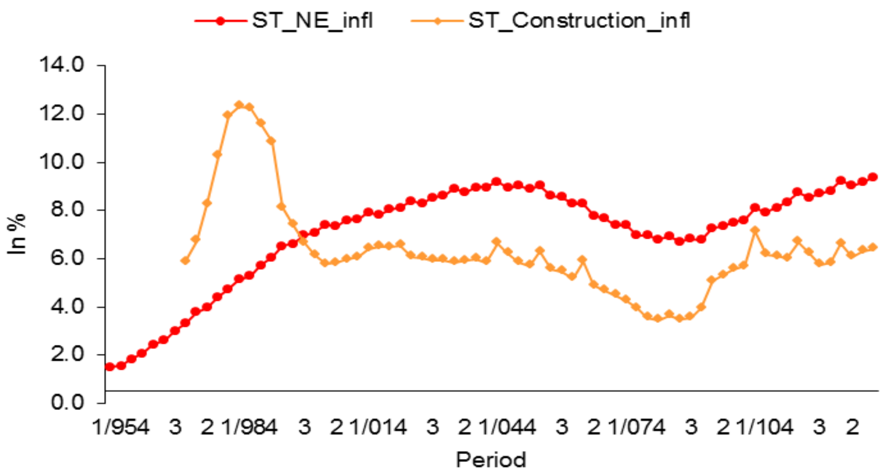

Fig. 3: NAIRU according to the Stochastic trend in the NE and in the construction sector (Source: Our own calculation based on data from the Ministry of Labour and Social Affairs, the Czech Statistical Office and the Czech National Bank)

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From the analysis of results obtained by the **Stochastic trend** follows that:

1) NAIRU values in the **national economy** were located in the interval from 1.5 to 9.3% and in the **construction sector** in the interval from 3.5 to 12.3%.

2) In comparison with the method of the HP filter and the Kalman filter, NAIRU values in the **national economy** corresponded with the real unemployment rate even more closely. In the **construction sector** the NAIRU values ranged further around the real specific unemployment rate than in the case of the HP filter and closer than in the case of the Kalman filter.

3) This model placed the period of transformation of the Czech economy in the time period from the 4th quarter of 1998 to the 1st quarter of 2001, which is in accordance with the Kalman filter estimate. Comparison of the results of all the three methods and the real data shows that in the Czech Republic it is possible to accept the conclusion of the authors regarding the usage of the local linear trend to increase the credibility of the NAIRU estimate. [12] This method identified the period of transformation of the economy in the **construction sector** in the period from the 4th quarter of 1996 to the 4th quarter of 2001. The HP filter identifies the beginning of this phase in the 1st quarter of 1996 and the Kalman filter only in the 4th quarter of 1998. Each of the methods also sees the end of the process of transformation on the labour market differently. Even though the Stochastic trend corresponded with the development of the real economy, its results did not cover the whole period and therefore we cannot consider the authors' suggestion to expand the random walk as legitimate. [12]

4) In the **national economy** the estimate of the positive gap and the boom phase in the period of 2nd quarter of 2007 to the 4th quarter of 2008 overlaps with the estimate of the HP filter, which corresponded with the development of the unemployment rate and the GDP. The conformity of the estimates of the Stochastic trend and the real data is supported by the suitability of the random walk adjustment. Positive gaps in the **construction sector** were found in the period from the 2nd quarter of 2007 to the 4th quarter of 2010. The Kalman filter estimated the beginning of this period as the earliest (2nd quarter of 2005), followed by the Kalman filter (3rd quarter of 2006). The end of the phase was firstly estimated by the Kalman filter (3rd quarter of 2007) and then by the HP filter (4th quarter of 2008). A boom phase on the labour market defined in a such way corresponds with the development of the real economy. As the results of the Stochastic trend did not cover the whole period, we cannot consider the authors' suggestion to expand the random walk as legitimate. [12]

5) The influence of the recession on the labour market in the **national economy** can be traced in accordance with the data just like in the case of the HP filter from the 2nd quarter of 2009 to the 1st quarter of 2011. Again, the consistency of the estimates of the Stochastic trend and the real data suggests that the authors' adjustment of the random walk was done correctly. [12] In the **construction sector** the recession started to be apparent in the 1st quarter of 2011 and lasted until the 4th quarter of 2012. Each of the methods defined the beginning of the phase very differently. The recession took place the earliest according to the Kalman filter (4th quarter of 2007), after that it was detected by the HP filter (1st quarter of 2009). The method of the HP filter and the Stochastic trend estimate the boom phase in contradiction to the date of the real economy and they both identify the end of the year 2012 as an end of this phase. This period also corresponded to the real economy development. Since the Stochastic trend put the beginning of the transition between the phases of boom and recession with a significant delay, it is also in contradiction with the authors of the random walk. [12]

6) The development in the period from the 2nd quarter of 2011 to the 4th quarter of 2012 in the **national economy** was characterized by the fact that the labour market was only in the boom phase. According to the Kalman filter and the HP filter the boom phase lasted only until the 3rd quarter of 2012 and in the following quarter the labour market returned to the phase of recession. As the comparison of the obtained estimates with the development of the real data confirmed the presence of the recession on the labour market in the last quarter, the authors' expansion of the random walk in the case of the Stochastic trend cannot be considered as positive. [12]

CONCLUSION

The paper surveys the comparison of the economic cycle on the labour market in the whole national economy and in the construction sector in the Czech Republic through the variable NAIRU. We see the difference between the estimated values of NAIRU and the real unemployment rate as an indicator of the economic cycle on the labour market. For the verification of the phases of the economic cycle on the labour market obtained by econometric statistical methods we used statistical data.

The significance of such researches lies in the fact that economic policy makers can use them to derive a level of stable and non-inflation economic growth, to assess the economic growth and the efficiency of structural, macroeconomic and microeconomic reforms.

From the analysis we carried out following these overall conclusions:

1) The NAIRU values in the **construction sector** measured by the method of the Stochastic trend ranged further around the real specific unemployment rate than in the case of the HP filter and closer than in the case of the Kalman filter. The Stochastic trend put the values of NAIRU for the **national economy** in the interval of 1.5 to 9.3% and in the **construction sector** 3.5 to 12.3%.

2) The method of the Stochastic trend placed the period of transformation of the **Czech economy** in the time period from the 4th quarter of 1998 to the 1st quarter of 2001, which is in accordance with the Kalman filter estimate and with the development of the real data. The HP filter puts its beginning in the 1st quarter of 1999 and its end already to the 1st quarter of 2000. In the **construction sector** the method of the Stochastic trend put the period of transformation of the economy into the period from the 4th quarter of 1996 to the 4th quarter of 2001. The HP considers as a beginning of this phase already the 1st quarter of 1996 and the Kalman filter only the 4th quarter of 1998. Each of the methods also sees the end of the labour market transformation elsewhere. The HP filter sets it into the 4th quarter of 1998 and the Kalman filter considers it the 4th quarter of 2003.

3) The estimate of the positive gap and the boom phase in the **economy** by the Stochastic trend, which puts it into the period from the 2nd quarter of 2007 to the 4th quarter of 2008, overlaps with the estimate of the HP filter. According to the Kalman filter this phase did not begin until the 4th quarter. The positive gaps in the **construction sector** were detected in the period from the 2nd quarter of 2007 to the 4th quarter of 2010. However, the earliest beginning of this period was estimated by the HP filter (2nd quarter of 2005) and was followed by the Kalman filter (3rd quarter of 2006). The end of this phase is estimated the earliest by the Kalman filter (3rd quarter of 2007) and then by the HP filter (4th quarter of 2008). A boom phase on the labour market defined in this way is therefore in accordance with the real economy development.

4) According to the Stochastic trend in the **economy** we can trace the influence of recession on the labour market in compliance with the data just like when we use the HP filter: from the 2nd quarter of 2009 to the 1st quarter of 2011, that is one quarter ahead of the estimate of the Kalman filter. In the **construction sector** the recession came through from the 1st quarter of 2011 to the 4th quarter of 2012. The methods set the beginning of this phase very differently. According to the Kalman filter the recession started the earliest (4th quarter of 2007). It was followed by the HP filter (1st quarter of 2009). All the methods except for the Kalman filter (which estimates the boom phase in contradiction with the real economy data development) agree that the end of this phase was at the end of the year 2012.

5) According to the Stochastic trend the development in the period from the 2nd quarter of 2011 to the 4th quarter of 2012 in the **economy** was characterized by the fact that the labour market was only in the boom phase. According to the Kalman filter and the HP filter, the boom phase did not last longer than until the 3rd quarter of 2012 and in the following quarter the labour market returned into the phase of recession.

The overview of specific conclusions of the analysis showed that the estimates of the unobservable variable NAIRU and the derived economic cycle on the labour market differ, depending on the used statistical econometric method. While the HP filter and the Stochastic trend were in a close correspondence with the development of the real unemployment rate, the Kalman filter followed them only loosely. However, in most periods the estimates of all the methods reflected the real development in the real economy, which was outlined by the published data. This fact confirms that they are suitable for application in the economic policy measures, most importantly in terms of support of the economy in recession. This support is significant mainly for the construction sector, in which the recession phase starts the earliest and ends the latest. Recession also usually has a deeper impact on this sector than on the economy as a whole. Measures leading to mitigation of recession or shortening of the phase of recession in the construction sector can have a positive influence on the development of the cycle in the whole economy.

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Internet sources

Czech National Bank

Foreign exchange rates

http://www.cnb.cz/cs/financni_trhy/devizovy_trh/kurzy_devizoveho_trhu/denni_kurz.jsp

Czech Statistical Office

Consumer price index

http://www.czso.cz/csu/csu.nsf/kalendar/aktual-isc

Construction work price index

http://www.czso.cz/csu/csu.nsf/kalendar/aktual-ipc

Import price index

http://www.czso.cz/csu/redakce.nsf/i/ceny_vd_ekon

Ministry of Labour and Social Affairs

Registered unemployment rate

http://www.mpsv.cz/cs/869

THE IDENTIFICATION OF A GROUP OF SETTLEMENT KNOWN AS "HIRZŮV ÚJEZD" BY ČERNÁ V POŠUMAVÍ

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ABSTRACT

Though small in area, Hirzův Újezd [1] was valuable, mostly because of its strategically important location on the Linec trail. From today's point of view, its value lies in its compactness and in the fact that it was probably founded by a single locator – Hirzo, which is in this size rare in our country.

This paper consists of identifying the aggregate of Hirzův Újezd and its development from its probable founding up to the present. The village identification method is based on the study of accessible historical records, which were partly uncovered by Jiří Kuthan. The method used for the determination of the presumed original founding concept is predominantly grounded in the research of Z. Pešková and J. Škabrada and is accepted among proffessionals.

The survey of the area identified all thirteen settlements, twelve of them were still well-preserved shortly after the end of the World War II. Unfortunately, only three of the settlements were preserved to the present day in a good condition and another three only as fragments.

This information will be used as a base for further study of the settlement-founding systems in the examined area (dissertation on the topic of Identification of surveying methods of locator Hirzo). By better understanding of the founding process of a settlement, we can obtain materials for protection of valuable and in many places still visible original structure, for example by projecting it into Spacial planning.

KEYWORDS

urbanism; colonization; 13th century; burgrave Hirzo; Hirzův Újezd - Hirza's Domain

INTRODUCTION

Hirzův Újezd [2] was, despite its relatively small size, historically valuable, mainly because of its strategical position on the important „Linecká zemská stezka“[3] which led through it (specifically, through Mýto and Dolní Vltavice) from the royal castle in Boletice to Kovářovice and further, up to Haslach in Austria [4].

From today's point of view, the value of the domain is mainly in the person of its likely locator, Hirzo [5]. In this country, it's comparatively rare for a single person who probably founded several settlements [6] in such a compact group and amount (up to 13 villages are ascribed to him [7]) to be directly known.

The goal of this paper is to identify the group of „Hirzův Újezd“ and its individual settlements, both the villages that were preserved to this day and those that disappeared. With villages thus found, I will search for their ground plans with the best correspondence to the probable structure of the original founding – their survey systems [8]. With the disappeared villages, I will also determine the probable time of their disappearance.

This paper is also about the first part my PhD thesis I'm currently working on with the theme "Identification of the Survey Systems of the Locator Hirzo and their Present Use" [9]. The goal of this work is to find an answer to the question if it's possible to find the original survey systems of Hirzův Újezd, which has, in present time, partially disappeared and, first and foremost, was forgotten, and if it's possible to find, as a part of this group, certain unifying elements – a foundation system that would lend support to the theory that these villages were indeed founded by a single locator (Hirzo) or by his group. This could even give another view of the possible evaluation of survey systems from the Middle Ages and the deeper understanding of the original way of founding could give us materials for possible protection of valuable, and often still recognizable original structure of the settlements.

As the direct protection of the settlements does not seem to be really possible (as the settlements are not preserved enough to be put under a conservational protection), it seems optimal to project this information into the process of Regional planning, using Master plans as a part of Regional planning materials. This does not require any legislative changes and allows to intervene more or less immediately [10]. We could use this as another way to help protect the heritage of the past from destruction through continuing improper interventions in the character of our villages.

METHODS AND THE SCOPE OF THIS WORK

The method of village identification is based on the study of available historical sources that were sketched by Jiří Kuthan [11] and also mentioned by J. V. Šimák [12] who also claimed that the colonization of the domain was very likely finished during the Hirzo's period of ownership. To determine the survey systems – the original foundation, and therefore also the urbanistic conception of the settlement – I use the method, already accepted among the expert public, resting on the relatively recent research of Z. Pešková and J. Škabrada [13].

The scope of this work is defined by the activity (as far as can be found) of the locator Hirzo in the group of villages known as Hirzův Újezd [14]. The main sources are two documents mentioning the list of the villages of Mokerský Újezd for the first time: a document of the King Přemysl Otakar II about the donation of Hirzo, the Zvíkov burgrave, to the Zlatá Koruna abbey from 27th March 1268 [15], and a document of the king Václav II from 11th January 1284 confirming said donation [16].

IDENTIFICATION AND LOCATION OF SETTLEMENTS

During the 13th century, the colonization activity in the Českobudějovicko [17] locality was at its peak, there were changes in the settlement structures, the foundation of the stable village net and vicarage organizations were laid down. A large amount of medieval towns and monasteries were founded [18]. The area of 13th century Českobudějovicko was not easily accessible – not just because of the enclosed vegetation, but mainly because of large amount of unpassable peat bogs of various types and various stages of development [19]. The proof of the increase of colonization activity in the České Budějovice basin during the end of the 12th century and during the 13th century are the surveys of plant macroremains and the reconstruction of the landscape changes during that time. These paleobotanical indicators suggest a vast reduction of the forested areas [20]. It can be proved, that in this period, Hirzo, as the burgrove, participated in the construction of the Zvíkov castle; he was also present at the construction of the royal town of Písek and, most importantly, at the foundation of the town of České Budějovice [21]. These facts incontrovertibly point to the importance of Hirzo's person, not only in the Českobudějovicko locality but also in the kingdom as such. Hirzo was most likely also a part of another location venture – the foundation of the town Netolice which was created by enlarging of the market settlement Staré Město in the vicinity of St. Václav's church in the middle of 1260s. There is also a possibility that Hirzo had his hand in the foundation of the royal town of Vodňany in the newly created demesne Hluboká. The ground plan of this town shows striking concordances with the disposition of České Budějovice. Unfortunately, the creation of this town is not supported by written reports [22].

The person of Hirzo is also tightly related to the Cistercian abbey in Zlatá Koruna, founded right during the time when Hirzo worked in this locality – in 1263, by the king Přemysl Otakar II. The important position of the monastery in this locality is also confirmed by the king's gift: a relic, Jesus Christ's crown of thorns [23]; the monastery also owned vast estates in Netolicko and Boleticko [24], directly adjacent to Hirzův Újezd. After Hirzo's death, it became the property of the monastery thanks to his donation.[25] The locality in question was an important communication and trade line; the important "Linecká zemská stezka" [26] passed through there, beginning in Linz and going through Cáchlov (Freistadt), the country gate in Dolní Dvořiště, Kaplice, Velešín, Doudleby, České Budějovice where it split in two branches. One branch led to Netolice, Vodňany and Písek, the other one to Soběslav, Tábor and Prague. Another trail, "Vitorazská stezka", led from the Austrian monastery Světlá (Zwettl) through Vitorazsko to the country gate in the Novohradské hory mountain range to Trhové Sviny and through Doudleby to České Budějovice where it joined „Linecká stezka“. Also, one of Zlatá stezka's branches (of so-called Prachatice system) led in the direction of Netolice and Vodňany, joining Linecká stezka [27] (which had Hirzův Újezd on it) at Lhenice.

The main source for the identification of the villages of Hirzův Újezd are two documents that mention the complete list of Mokerský Újezd villages for the first time: a document of the King Přemysl Otakar II confirming the donation of Hirzo, the Zvíkov burgrave, to the Zlatá Koruna abbey from 27th March 1268 [28], and a document of the king Václav II from 11th January 1284 [29], once again confirming this donation. This document is also the first historical source that mentions the villages themselves (without being tied to the group as such) [30]. If we additionally take into account that the number of estates in the group is not growing since that first mention [31] and that the name, with exception of those which were probably "officially" germanized [32], are of Czech origin, it confirms the presumption that this area was colonized mostly by Czech people from the interior in the period when the group was owned by Hirzo, who basically finished the colonization of this area in this manner. This is also confirmed by Krumlov registers from 1445 [33]. Other valuable materials are the archives of Czech monasteries abolished during the reign of Josef II [34], which clearly once again show the transformation of village names into a germanized form between 1483 and 1513. This is now very similar to the names from the age of making of Indikační skici – a stable land register from 1826-1843 (for Bohemia) [35]. The correct assignment of village names in the present (19th-20th century) is then verified by direct search and compared with the database of villages that no longer exist (for example in: www.zanikleobce.cz).

As can be clearly seen from Table 1, all the villages have been traced back to the beginning of the 16th century. At the beginning of the 19th century, it is still possible to find 12 of them, including the sufficiently expressive ground plans. There is a whole gamut of settlements, from small ones that are basically just groups of several objects (Jankov, Skladné-Skalní, Dětochov) through villages with clear object groupings at one side of the village square line (Mladoňov, Záhliní) to villages with clearly defined village square and many objects by its sides (Hořičky, Radslav, Mýto, Mokrá, Dolní Vltavice, Bližná, Černá v Pošumaví) – which show character-location founding [36]. Namely, the research of Z. Pešková showed that the states shown at Indikační skici may be considered sufficiently evidential, illustrating the likely structures of the villages' foundation [37]. In fact, there are no other options. The archaeological surveys of this locality are practically nonexistent [38] and Indikační skici - Císařské otisky map stabilního katastru [39] are the first materials that more or less correctly describe the object locations, including the relation to the agricultural area.

In the era shortly after the end of the WWII, we are able to use extremely precise materials in toe form of plane photos [40] which, in combination with SMO-5 maps and Indikační skici, allow identification of these villages with a high degree of certainty. 12 villages of the original Hirzův Újezd were successfully identified in this locality and time period: Hořičky, Mladoňov, Radslav, Jankov, Skalní, Dětochov, Mýto, Mokrá, Záhliní, Černá, Bližná and Dolní Vltavice. Unfortunately, only three settlements (Mýto, Mokrá and Černá) were preserved until present in relatively good state and three others (Radslav, Bližná and Dolní Vltavice) were preserved in fragments. This radical development was partially caused by the global decline of border areas after the WWII; all settlements in the area show devastation in the years shortly after the war, but the greatest direct impact happened at the settlements Záhliní and Bližná. However, the greatest damage was undoubtedly done by the foundation of military domain Boletice which led to the disappearance of settlements Hořičky, Mladoňov and Dětochov [41] and the construction of the Lipno reservoir which caused the demise or strong modification of the settlements Dolní Vltavice and Radslav [42]. I study this problem from the point of view of an architect-urbanist and given the goals of this survey, I haven't done further historical research on this problem.

As this article does not have much space, I only present the map materials I found for all the villages only for Indikační skici (Figure 1-4) and only for one village – Mokrá – I show the complete summary of the map materials from all key periods (Figure 5-7). This village, although it does not have a typical locational ground plan, was chosen for illustration because it had the least intravilan changes while being preserved to the present (the complete summary of data found is shown in an easy-to-understand way in Table 1). When comparing all the villages, it can be clearly seen that several of them show signs of clear locational founding. The next planned step is to analyse directly the foundation modules and compare them with the surrounding villages [43]. The research done clearly shows that despite great changes the locality in question underwent, especially after the WWII, there is still a possibility to save and conceptually develop all the settlements of Hirzův Újezd, not just the ones that were relatively well-preserved.

Tab. 1: Searching for the individual village names – summary table

Document from 1268 [A]	Document from 1284 [B]	Krumlovské registry 1445 [C]	Monastery archive 1483 [D], 1513 [E]	„Stabilní katastr" 19th century [F]	1st half of 20th century [G]	the current state [H]
Nakhlenwe Hore // Nakhlewe Hore	Klenow [TS, JAG, FAK]	Clenowicz [TS]	Horžiky [FAK] ?= Hőrwitz = Hořičky [FAK]	Hőrwitz	**Hořičky** [CD, CD, H] ~~Klenow~~ [CD, MAP, MAP]	**disappeared immediately after 1947** [I]
Vgerc // Vgere	Jercenslag [TS, PRU]	Prowodicze [TS]	~~Vgeed~~ [FAK] ~~? = Probolden = Prowodicze~~ [FAK, MAP]	X	**X**	**probably disappeared in the period 1483-1513**
Vmlatone // Vmladone [PRU]	Dietchslag [TS, PRU]	Detochovice [TS]	Diethoch [FAK]	Plattetschlag [PRU]	**Mladoňov** [CD, PRU]	**disappeared immediately after 1947** [I]
Naochruhle	X	Okrouhlá [PRU]	Radslaw [FAK]	Rothschlag	**Radslav** [PRU, CHV] Okrouhlá [CD, MAP]	**partially submerged in 1951-1958** [J]
Vyanka	Jenkeslag [TS, JAG, FAK, PRU]	Jankov [TS]	Jankow [FAK]	Janketschlag [JAG, FAK, PRU]	**Jankov** [JAG, CD, PRU, CHV]	**gradual disappearance after 1945** [L]
Nabelem Chlume	Zkalni [TS, JAG, FAK]	Skalny [TS]	Skalny [FAK] ?= Janketschlag = Jankow [FAK]	Finketschlag [JAG, FAK, PRU]	~~Skalní~~ [JAG] **Skalné** [CD, CD, PRU, CHV, MAP]	**gradual disappearance after 1945** [M]
Vdirko	Jurizlag [PRU]	X	~~Asching = Lišín = Lislin~~ [FAK]	~~Inesdorf=Lišín~~ [PRU, FAK, CHV] (confused, settlement by Záhoří) [MAP]	**Dětochov**=Tichthöfen [PRU, CD, CHV] Dichthöfen [MAP]	**disappearance immediately after 1947** today's Květušín [N]
Vmica	Mucztat [TS, JAG, FAK, PRU]	~~Mokry~~ [TS, CHV]	?= Mautstatt = Mýto [FAK]	Maustadt [JAG, FAK, PRU]	**Mýto** [JAG, CD, PRU]	**preserved**
Nemochrich // Nemochrih	Mokrle [JAG, FAK, PRU]		Mokra [FAK]	Mugrau [JAG, FAK]	**Mokrá** [JAG, CD, PRU]	**preserved**
Vhlimi	Zahdini [TS, JAG, FAK, PRU]	Zachlynie [TS]	Zahlinie [FAK]	Eisengrub [JAG, FAK]	**Záhliní** [JAG, CD, PRU]	**gradual disappearance after 1945** today, only fragments remain [O]
Natschemerece	Nachirnie [TS, JAG, FAK, PRU]	Czerno Swarzpach [TS]	Czerno [FAK]	Schwarzbach [JAG, FAK]	**Černá** [JAG, CD, CD, CD, PRU]	**preserved** expanded and reconstructed
Nablisnich	X / ~~Blyzny~~ [TS, FAK] ?sometimes mentioned as Budeczlag [KRO]	Bikarczlag [TS]	Blizna [FAK]	Egetschlag	**Bližná** [CD, PRU]	**gradually disappeared after 1945** several estates preserved
Nahyrzowe	Hirzow [JAG, FAK, PRU] / Hirzov [TS]	Wultawicze [TS]	Witauia [FAK]	Untermoldau [JAG, FAK] Wuldau [PRU]	**Dolní Vltavice** [JAG, CD, PRU]	**mostly submerged in 1951-58** [P]
	Budeczlag [FAK] – probably disappeared before 1375 [KRO] **and in its place, newly ->**		X / **?=Schlackern=Slawkowice** [FAK]	~~Slack?~~ [FAK] ~~Schlackern~~ [PRU] **Slawkow, Slabs** [KRO]	~~Budiče~~ [PRU] ~~Budice~~ [FAK] ~~Slavkov~~ [KRO]	**probably disappeared before 1375** [KRO]

*The references (in [ ]) and potential ~~exclusion~~ of some settlements is explained on the following sheet. **Bold** settlements are those that were determined with confidence, including usable map materials for further study.*

Table legend, Notes for settlement identification in Table 1:

All settlements were checked in the map materials (Stabilní katastr – plane photosurvey 1946 – current satellite maps 2014) during identification verification. I now list the explanations about their identification and potential exclusion of some settlements mentioned in the literature as a part of Hirzův Újezd. These are direct references from Table 1.

JAG*/ Only for these villages Jagr (JAGR S. and ZÁHORA F. Kronika obce Černá v Pošumaví (Chronicle of the village Černá in Pošumaví), transl. 1995, for download at* [*http://www.geosumava.cz/web/index.php?web_show=dokument*](http://www.geosumava.cz/web/index.php?web_show=dokument)*) claims that the current name of* *the village can be provably found. Josef R. Hahnel says, in his chronicle, that the data was taken from the archive of the castle of the prince Schwarzenberg in Krumlov. "Through the benevolent interposition of the head director of the archive, Mr. Dr. Tannich, the mayor of Krumlov, did His Highness grant a special authorization to the writer of the village chronicle to perform the necessary research for the aforementioned village chronicle. For the reason of distance in space, this part of the work was done by the teacher Mr. Leopold Eichler from Krumlov."*

FS*/ The identification was performed by the chronicler and author of large amount of articles about the Vyšebrodsko region František Schusser, In: http://www.horniplana.cz/clanek.php?id=396*

CD*/ Identification according th the information from FRIEDRICH,DUŠKOVÁ,VAŠKŮ.Codex Diplomaticus Et Epistolaris Regni Bohemiae Tomi V. Pragae MXMIII. p.94-279.*

ČO*/ Translations listed in the analysis "Přívlastková místní jména z materiálu 11. – 13. Století" (Adjective local names from the 11th–13th century sources), In: ČORNEJOVÁ, Michaela. Místní jména z materiálu 11. – 13. století (Local names from the 11th–13th century sources). IN: Acta onomastica 47.140-50,2006.*

PA1*/ Source: PANGERL, Stift Goldenkron (=FRA II/37, Wien 1872), S. 32, Nr. 10, commentaries to the donation document "Konig Wenzel II. bestätigt die Güterschenkung des Hirzo (Hrz) Burggrafen zu Klingenberg an das Kloster Goldenkron." Available at: http://monasterium.net/mom/CZ-NA/AZK/1284_I_11/charter.*

PA2*/ Source: PANGERL, Anhang Stift Goldenkron (=FRA II/37, Wien 1872) S. 617-622, Nr. 44. Commentaries to the document – names listed here can be found directly in the document.*

PA3*/ Source: PANGERL, Stift Goldenkron (=FRA II/37, Wien 1872), S. 579, Nr. 254. Commentaries to the document – the names cannot be gleaned from the document – assignment is only in the commentaries.*

PRU*/ PRUSIK, František – Pomezný hvozd a nejnovější spisy o něm (Pomezný hvozd and the latest treatises about it). Sborník historický 1885. Printed and published by J. Otta, pp. 9-16; 111-119; 169-177.*

KRO*/ The original German chronicle of the village of Černá v Pošumaví. Volume one, until 1945.*

KRO2*/ The chronicle of the village Černá v Pošumaví. Volume two, 1977-1989. The author, Ing. František Záhora says that his source was Státní archív in Český Krumlov, but unfortunately he does not specify anything more. He is not the only author mentioning this hypothesis, for example also František Prusik In. : Pomezný hvozd a nejnovější spisy o něm (Pomezný hvozd and the latest treatises about it). Sborník historický 1885. Printed and published by J. Otta, pp. 111-119.*

CH1*/ CHYTIL, Alois. Chytilův úplný adresář království Českého (Chytil's complete directory of the kingdom of Bohemia). Prague 1915.*

CH2*/ CHYTIL, Alois. Chytilův Místopis ČSR (Chytil's topography of ČSR) 2nd edition. Prague 1929.*

Author's Note:

CHy1*/ This is apparently an error (probably during transcription) when the settlements Mokrá and Mýto were confused (see the reference FS).*

CHy2*/ No other publication, nor the original document, lists this site here, so it's very likely an error or an imprecise settlement inclusion (see FS)*

MN1*/ Most likely a simple confusion in the text of the article , the settlement definitely corresponds to Hořičky.*

MAP*/ Confirmed in the map materials by confronting the maps of Stabilní katastr, the maps of SMO-5 and the military mappings. Present state checked via satellite photos.*

[A] Document of the king Přemysl Otakar II confirming the donation of Hirzo, the Zvíkov burgrave, to the Zlatá Koruna abbey from 27th March 1268 In: RBM II., No. 608, p. 236. (the literature more often uses the transcription of names shown in the first position (for example KUTHAN, Jiří. Zvíkovský purkrabí Hirzo – příspěvek k dějinám kolonizace Jižních Čech (Hirzo the Zvíkov Burgrave – A

Contribution to the History of Colonization of Southern Bohemia). Českomoravský časopis historický, XIX, 1971, No. 5, p. 719. after // shows the direct transcript from the original document)

[B] *Document of the king Václav II from 11th January 1284 confirming Hirzo's donation. In: RBM II., No. 1309, p. 564. (the first position shows the direct name transcription from the document, which is available online: http://147.231.53.91/src/index.php?s=v&cat=8&bookid=132),*

[C] *Taken from František Schusser in: Hornoplánské listy, http://www.horniplana.cz/clanek.php?id=396. There is a problem with searching, as František Schusser, an author who spent most of his life researching the microregion of so-called "Vyšebrodsko" mentions Krumlovské registry as his source, as Kuthan does (see above), the closest to this work description is: SCHMIDT and PICHA. Urkundenbuch der Stadt Krummau in Böhmen II. Band (1420-1480). Prague 1910., however this name wasn't found here successfully, there is a question whether the author did actually mean this source.*

[D] *The archive of Czech monasteries abolished during the reign of Josef II (1715-1760), document from 1483 in: PANGERL, Anhang Stift Goldenkron (=FRA II/37, Wien 1872) p. 617-622, No. 44, available for example at: http://www.mom-ca.uni-koeln.de/mom/CZ-NA/AZK/1483_X_16/charter?_lang=ces*

[E] *The archive of Czech monasteries abolished during the reign of Josef II (1715-1760), document from 1513 in: PANGERL, Stift Goldenkron (=FRA II/37, Wien 1872), p. 579, No. 254.*

[F] *So-called "mandatory imperial imprints" in the scale 1: 2,880 that show the state during the mapping time (1826-1843 for Bohemia and 1824-1836 for Moravia and Silesia) are the key for the identification of the survey systems themselves (source: http://oldmaps.geolab.cz), and so the physical identification requires to determine their names in this time period.*

[G] *The materials are an air photosurvey of ČSR from 1947-1952 available for example at http://kontaminace.cenia.cz, names searched and checked using the SMO5 maps.*

[H] *The materials are current (2014) sattelite photos available for example at https://www.google.cz/maps/preview. (state on 1/9/2014 as for the Internet source dating)*

[I] *The foundation of military domain Boletice, for example the official website of ČR army at http://www.vojujezd-boletice.cz/*

[J] *The foundation of military domain Boletice, for example the official website of ČR army at http://www.vojujezd-boletice.cz/*

[K] *Construction of the valley reservoir Lipno 1951-58, for dating see the official website at http://www.lipensko.org*

[L] *Confirmed both on the map materials and with "Statistický lexikon obcí republiky Československé 1955", in 1950 there were 3 houses and 0 inhabitants, available for example at: http://www.zanikleobce.cz/index.php?menu=121&obec=616.*

[M] *Confirmed both on the map materials and with "Statistický lexikon obcí republiky Československé 1955", in 1950 there were 3 houses and 0 inhabitants, available for example at: http://www.zanikleobce.cz/index.php?menu=121&obec=616*

[N] *The comparison of plane photosurvey of ČSR from 1947-1952 with the current satellite photos clearly shows that the present settlement Květušín expanded to the position of the settlement Dětochov, which therefore no longer exists. The plane photos also show that the settlement disappeared – was disappearing during this exact period. The estates are heavily damaged and the photos indicate they are probably uninhabited; with surrounding settlements taken into account, we can assume that it disappeared after the displacement of Germans, i.e. cca after 1947.*

[O] *Confirmed both on the map materials and with "Statistický lexikon obcí republiky Československé 1955",in 1950 there were 6 houses and 35 inhabitants, available for example at: http://www.zanikleobce.cz/index.php?menu=121&obec=616*

[P] *Construction of the valley reservoir Lipno 1951-58, for dating see the official webpage at http://www.lipensko.org*

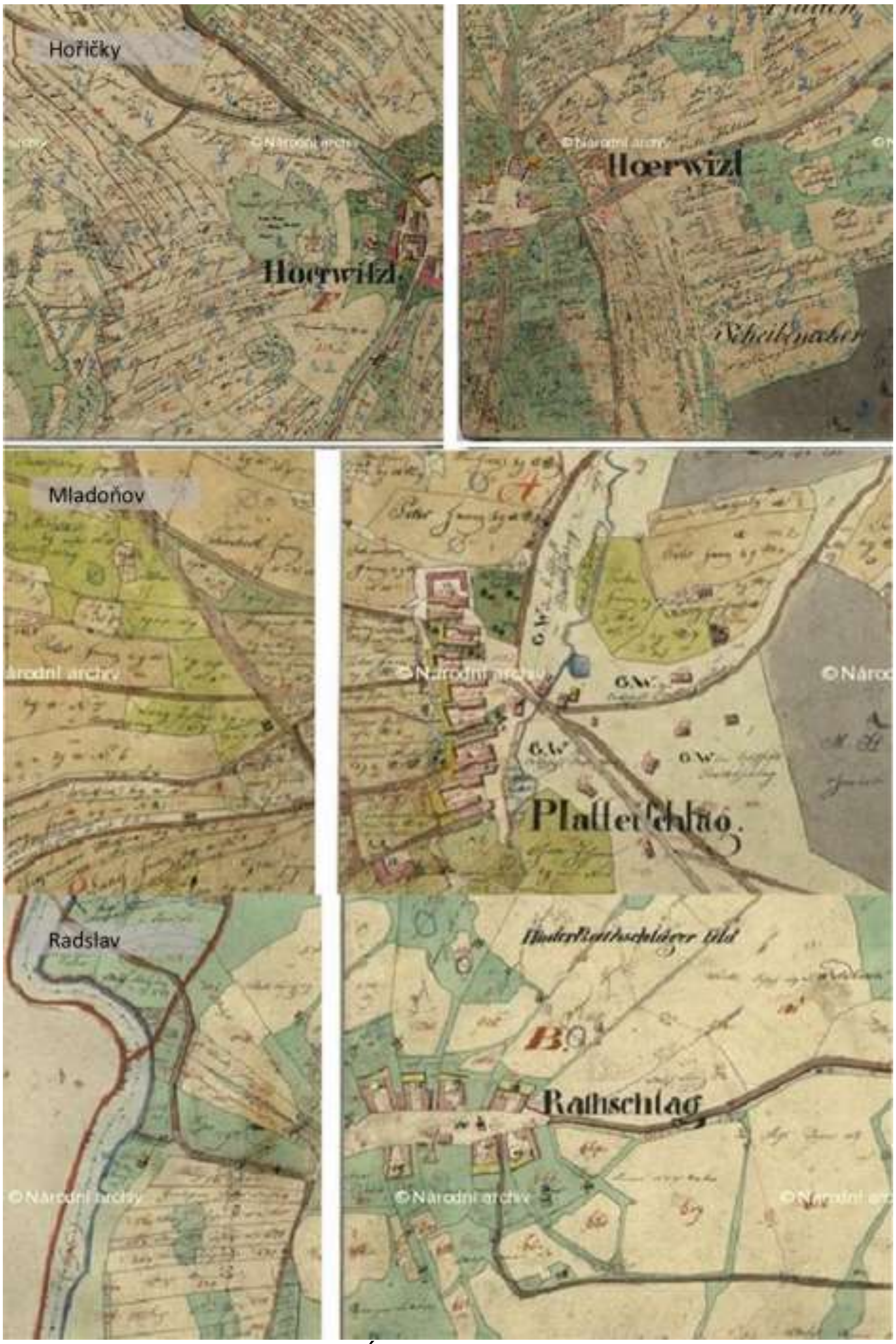

Fig. 1: The villages of Hirzův Újezd in "indikační skizzy" (author's archive)

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Fig. 2: The villages of Hirzův Újezd in "indikační skizzy" (author's archive)

DOI 10.14311/CEJ.2015.03.0015

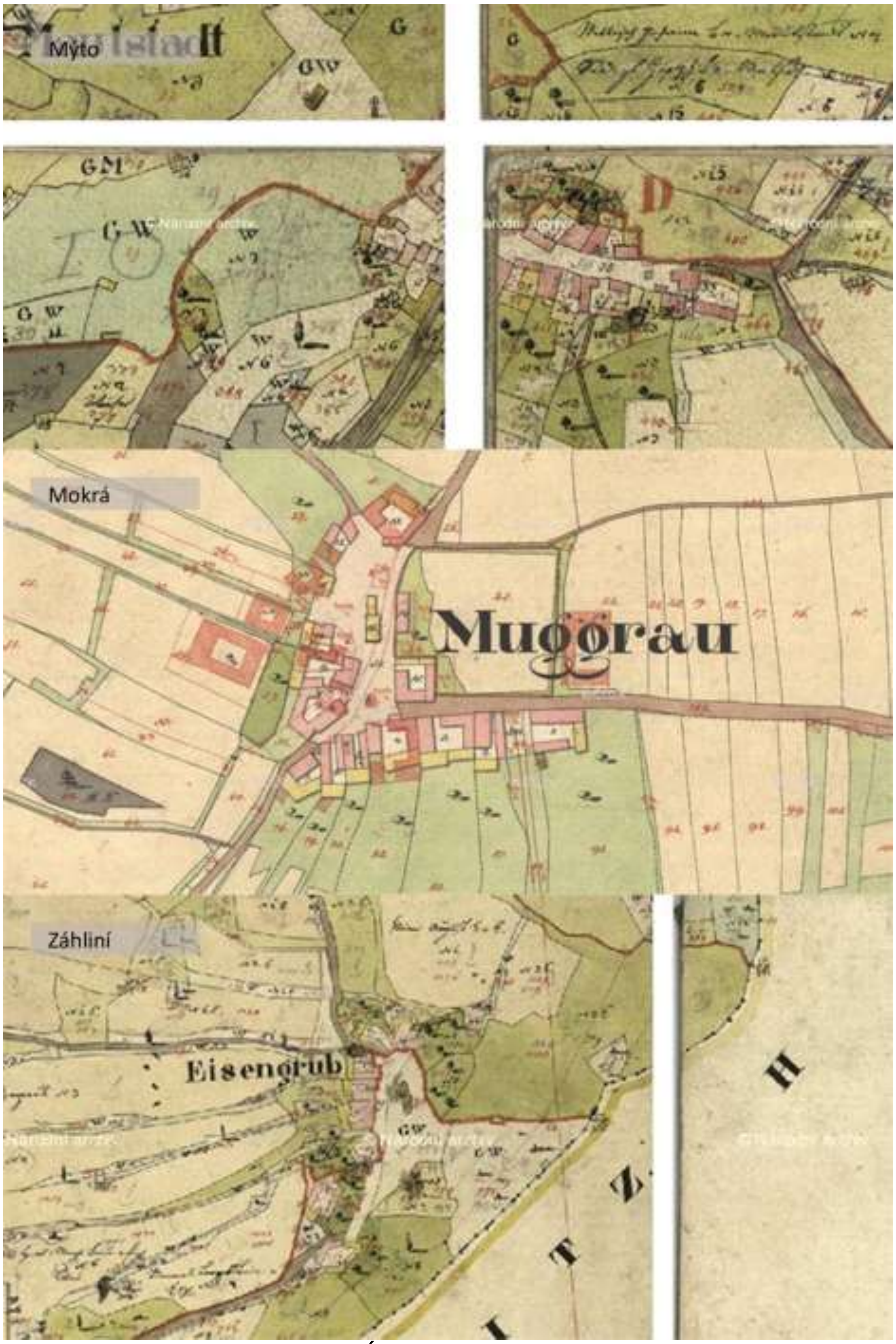

Fig. 3: The villages of Hirzův Újezd in "indikační skizzy" (author's archive)

Fig. 4: The villages of Hirzův Újezd in "indikační skizzy" (author's archive)

Fig. 5: Military mapping 1764-1878. (author's archive)

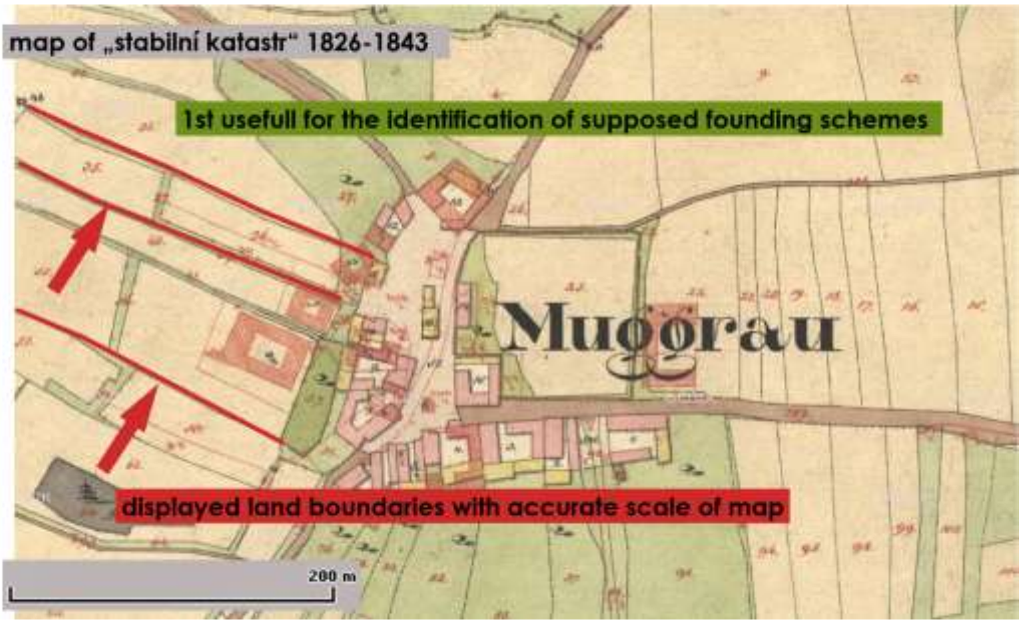

Fig. 6: Map of „Stabilní katastr" 1826-1843 and the oldest plane photosurvey from 1949-1952 .

DOI 10.14311/CEJ.2015.03.0015

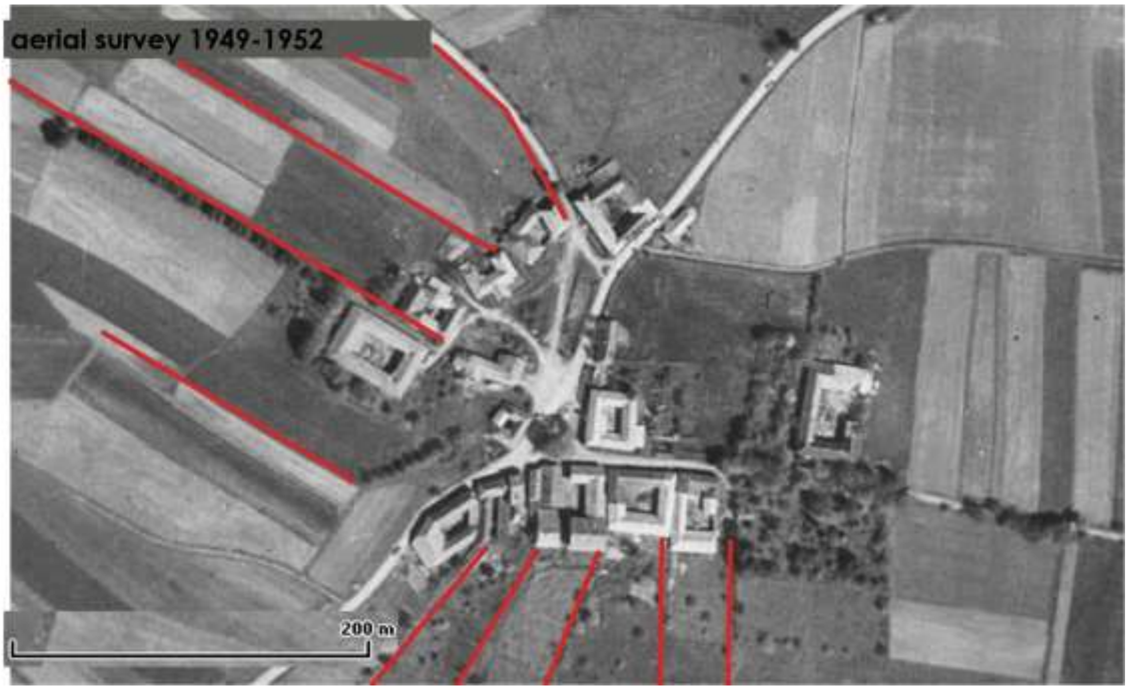

Fig. 7: Military mapping cca 1878/plane photosurvey 1949-1952 -> still preserved core of the village.

Fig. 8: Expected foundation date of still preserved buildings.

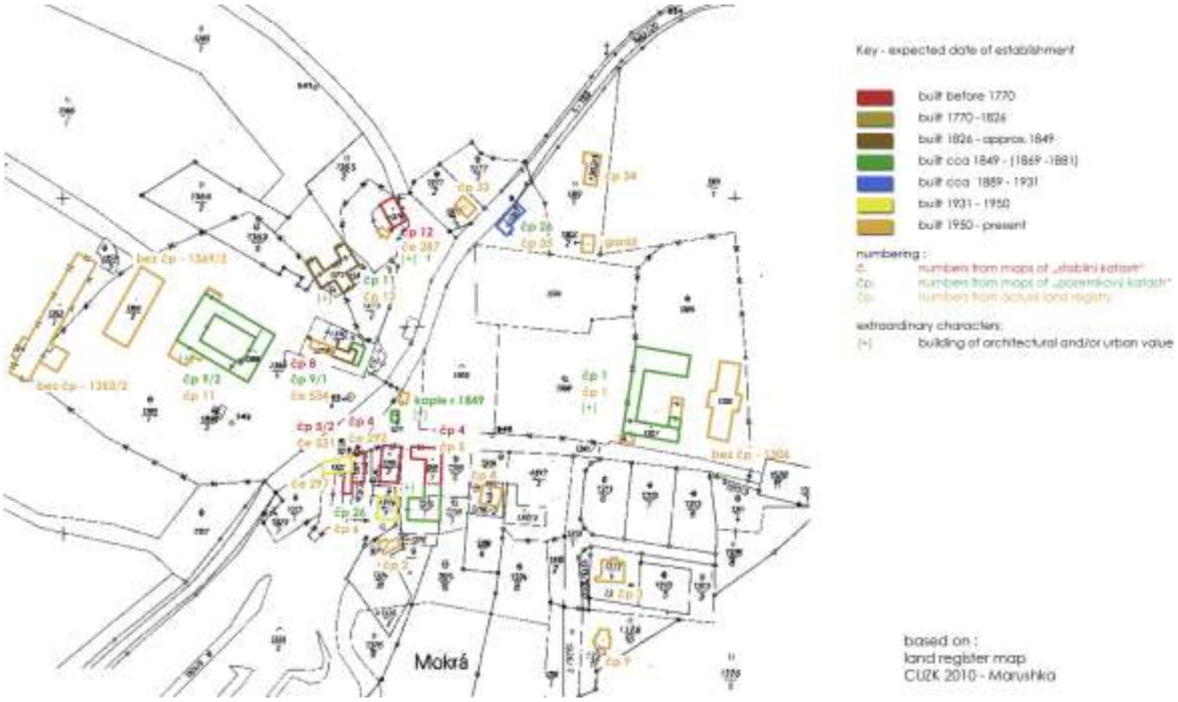

Fig. 9: Still preserved buildings fouded before 1900s and fragments of supposed medieval ground modules.

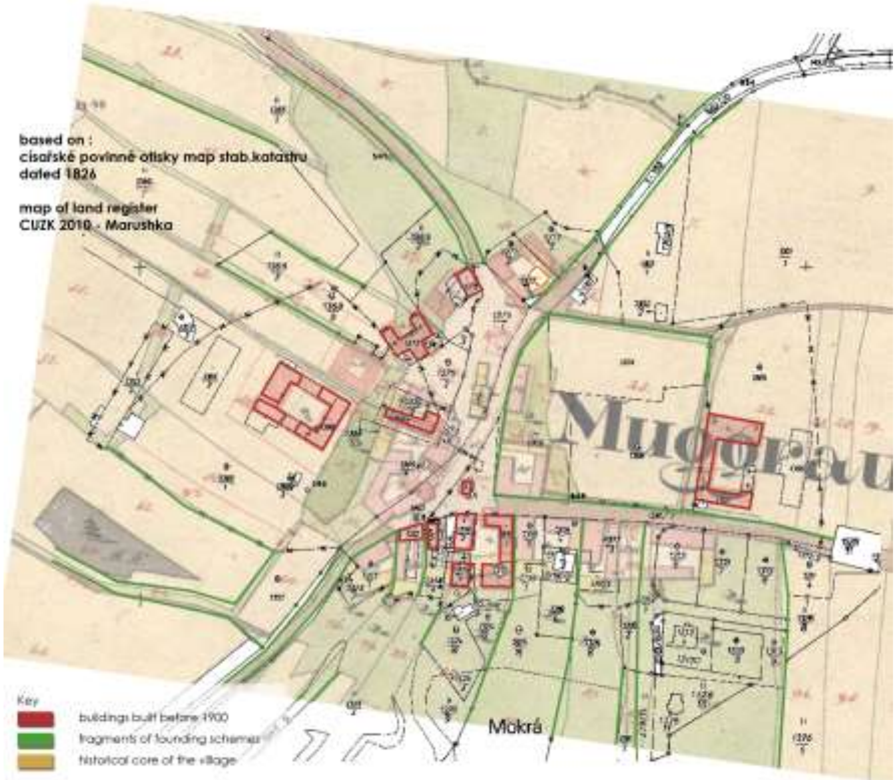

Fig. 10: Overlay of previously mentioned information layers

DOI 10.14311/CEJ.2015.03.0015

CONCLUSION

The research proved that it is possible to identify the individual villages of Hirzův Újezd and to map their development up until today. Out of the 13 villages listed in the document of the King Přemysl Otakar II from 27th March 1268 that confirms the donation of Hirzo the Zvíkov burgrave to the Zlatá Koruna abbey [44], the first mention of Hirzův Újezd, 12 villages were managed to be identified in the beginning of the 19th century and their ground plans (sufficiently describing their foundation conception) were successfully obtained from Indikační skici. Unfortunately, only three settlements (Mýto, Mokrá and the center of Černá) were preserved more or less intact and further three (Radslav, Bližná and Dolní Vltavice) can be found as fragments. This radical development was partially caused by the general decline of the border areas after the WWII, and especially by the foundation of the military domain Boletice which led to the disappearance of three settlements [45] and by the construction of the Lipno reservoir which caused the disappearance or substantial modification of further three settlements [46]. Table 1 describes the identification of these villages since their probable founding in 13th century until today. The likely original foundation of at least three of the settlements is still readable and it still seems to be possible to protect their partially preserved style (Figure 8. and 9.).

Writing down the knowledge about their probable original method of founding and the scope of their preservation into „Územně analytické podklady - territorial analysis for Master Plan“ could potentially allow the experts to reflect these values in „Spacial plan“ and therefore achieve their preservation ot at least pondering about the possibility to develop a settlement thus inspired.

DOI 10.14311/CEJ.2015.03.0015

REFERENCE

[1] Hirzův Újezd – Hirza's Domain
[2] Hirzův Újezd (the literature also sometimes calls it "Mokerský Újezd" for the most important village of the group – Mokrá) is named after the burgrave Hirzo who owned this domain before 1263, the first mention of his ownership comes from the doundation document of the Zlatá Koruna monastery (In: RBM II., No. 409, p. 158).
[3] Zemská stezka – Czech term for medieval trading track – road.
[4] KADLEC, Jan. Dějiny Zlaté Koruny (The history of Zlatá Koruna). České Budějovice 1949, p. 68.
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STATISTICAL ASSESSMENT OF QUANTITATIVE QUALITY PERFORMANCE OF BUILDING PRODUCTS DURING CONFORMITY ASSESSMENT AND CERTIFICATION IN THE FIRE PROTECTION FIELD

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ABSTRACT

This paper proposes statistical methods for evaluation of quantitative performance of building products determined by tests for objective decision during conformity assessment/certification in the fire protection field. The procedure is applicable even for other types of products, and for research / development of new material products.

KEYWORDS

Building products, quantitative quality performance, statistical assessment, confidence interval, confidence coefficient, certification

INTRODUCTION

On the Czech market the construction products are subject to Law No. 22/1997 Coll. [1] and the Government regulation (GR) No. 163/2002 [2] among other things. GR also obligates to examine the so-called "specified products". Every manufacturer shall demonstrate their compliance with the relevant standards. The reason is consumer protection from the point of view of health protection, fire safety, hygiene, energy saving and environmental protection. Annex 2 of the above-mentioned regulation shows the following main groups of products specified for conformity assessment:

- ✓ construction products for concrete and reinforced concrete construction parts,
- ✓ construction products for masonry constructions,
- ✓ building wood products and wood constructions,
- ✓ construction products for metal constructions,
- ✓ protective, thermal insulation materials and products, waterproof materials, roof covering and adhesives,
- ✓ glass building products,
- ✓ construction products for sewer systems and distribution of liquids and gases,
- ✓ construction products for hole fillings,
- ✓ special materials, products, structures and equipment,
- ✓ the technical equipment of buildings,
- ✓ construction products for internal and external finishes of walls, ceilings, floors,
- ✓ construction products for sanitary facilities and other special products.

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The European Parliament and Council Regulation (EU) No. 305/2011 (CPR) [3] also apply to the European market of construction products. According to this regulation the assessment obligation occurs when the products are determined by the requirements of the harmonized Czech (European) technical standards and/or European Technical Assessments (ETA). Manufacturers are entitled to label their products with the CE mark (CCZ is the Czech mark of conformity) after fulfilling the prescribed requirements.

The statistical assessment of the product's prescribed quantitative quality performance test values determined according to the prescribed test standards is an important tool for the objective determination whether the product meets/does not meet it.

STATISTICAL ASSESSMENT OF THE QUANTITATIVE RESULTS OF TEST DETERMINATIONS

The quality of the material construction products may be characterized by the test of a quality feature e.g. M, test-determined which has a specific value e.g. M_0 in a quality product. If the value $M = M_0 \pm U$ is found in the supplied sample of product in verifying the property M during certification/conformity assessment, its quality is confirmed and a certificate can be granted.
U is permissible tolerance's result.

Otherwise, if $M < M_0 - \Delta$, or if $M > M_0 + \Delta$, and Δ is $> U$ its quality is not confirmed and a certificate cannot be granted to it.
Standardized test method usually requires measurements of M product's property repeatedly n times with particular numerical results of $X_1, X_2, \ldots, X_n$.

Results of X_i $(i = 1, 2, ..., n)$ are not equal to M, but they have values of $X_i = M + u_i$ where u_i are the individual measurement uncertainties. We assume that the measured results were/are statistically evaluated to remoteness and outliers and that the remote values were /are excluded [5]. If these uncertainties are mutually independent and have normal distribution with the mean value Θ and the variance σ^2 or more precisely the standard deviation σ, then the following procedure can be used to evaluate the results of tests:

- the so-called confidence interval (CI) is determined for the M value so that there applies:

$$P\,(\underline{M} \leq M) \cong 1 - \alpha/2, \text{ that is } P\,(\underline{M} > M) \cong \alpha/2 \tag{1}$$

$$P\,(\overline{M} \geq M) \cong 1 - \alpha/2, \text{ that is } P\,(\overline{M} < M) \cong \alpha/2 \tag{2}$$

$$\text{Then } P\,(\underline{M} \leq M \leq \overline{M}) \cong (1 - \alpha), \tag{3}$$

The probability that the interval does not contain the actual value is approximately α.

Number $(1- \alpha)$, selected according to the severity of the consequences of errors (usually 0.90 or 0.95 or 0.99) is the so-called coefficient of reliability (confidence coefficient). Its complement to 1, equal to α, is the so-called Risk of mistake.

Under the assumptions (normality of errors distribution) the confidence interval has the following formula

$$\underline{M} = \bar{x} - \mu_{1-\alpha/2}\,\frac{\sigma}{\sqrt{n}}, \tag{4}$$

$$\overline{M} = \bar{x} + \mu_{1-\alpha/2}\,\frac{\sigma}{\sqrt{n}}, \tag{5}$$

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Where $\bar{x}$ is the sample average of the results

$$\bar{x} = \frac{1}{n}(x_1 + x_2 + \ldots + x_n) \tag{6}$$

and $\mu_{1-\alpha/2}$ is the so-called quantile of the standard normal distribution, defined by the formula

$$\Phi\,(\mu_{1-\alpha/2}) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\mu_{1-\alpha/2}} e^{\frac{-z^2}{2}}.dz = 1 - \frac{\alpha}{2} \tag{7}$$

For the most common values of α (0.1 or 0.05 or 0.01) the quantiles' sizes are listed in the following table [6]

Tab. 1: Quantiles of standard normal distribution for the selected values of errors' risks α

α	***1 – α /2***		***$M_{1-\alpha/2}$***
0.01	0.995		2.576
0.05	0.975		1.960
0.1	0.950		1.645
0.2	0.900		1.282

Decision-making about the product's ability to the given purpose/ compliance could be as follows:

$$\overline{M} > M_H = M_0 + \Delta, \tag{8}$$

this is the possibility that $M > M_H$ is not excluded, therefore the product does not meet the quality criterion and cannot be approved,

$$\underline{M} < M_D = M_0 - \Delta, \tag{9}$$

this is the possibility $M < M_D$ is not excluded. Again, the product does not meet quality criterion and cannot be approved,

$$M_D < \underline{M} < \overline{M} < M_H\ , \tag{10}$$

indicates with a high probability that M is among the permissible limits M_D and M_H and so the product can be approved.

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Degree of protection against possible error can be expressed as follows:

- If in fact

$$M > M_H = M_0 + \Delta, \tag{11}$$

then with the preselected high probability of *(1- α)/2* will be $\overline{M} > M_H$ and if $M > M_H$, the product is needed to be disapproved with a high probability ,

- If $$M < M_D = M_0 - \Delta, \tag{12}$$

then with the probability of *(1 - α)/2* will be $\underline{M} < M_D$ and the product must also be disapproved,

- If in fact, $$M \cong M_0 \tag{13}$$

(M equals to the correct value M_0), then with a high probability *(1 - α)* will be

$M_D < \underline{M} < M_0 < \overline{M} < M_H$ and the product can be approved (justified correct decision). An unpleasant/indecisive situation can occur when confidence interval ($\underline{M}, \overline{M}$) contains both the value of M_0, and one of the values M_D, M_H. In this case, the possibility $M = M_0$ (correct value) cannot be excluded, nor $M < M_D$ (M is too low) possibly

$M > M_H$ (M is too high). This situation can be avoided if the number of measurements n is chosen so that the length of the confidence interval

$d = \underline{M} - \overline{M}$ is smaller than Δ number, that is when

$$n = \min \{k, k_{integer}, k \geq \frac{4\mu^2_{1-\alpha/2} \cdot \sigma^2}{\Delta^2}\} \tag{14}$$

A simple calculation can convince us that in this case it is not possible that the interval ($\underline{M}, \overline{M}$) contains the correct value M_0, and simultaneously one of already unacceptable levels of M_D or M_H.

However, if the value of σ, characterizing the variability of the results of errors of measurement is not known, it should be estimated from the measurement results of $x_1, x_2, \ldots x_n$ according to the formula

$$s = \frac{1}{\sqrt{n-1}} \cdot \sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2}, \tag{15}$$

where $$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \tag{16}$$

Then the confidence interval is

$$\underline{M} = \bar{x} - t_{n-1,\alpha/2} \cdot \frac{s}{\sqrt{n}} \tag{17}$$

$$\overline{M} = \bar{x} + t_{n-1,\alpha/2} \cdot \frac{s}{\sqrt{n}} \tag{18}$$

where $t_{n-1,\alpha/2}$ is the so-called 100 $\alpha/2$ %-critical value of the Student's t-distribution with (n-1) degrees of freedom [6]. The length of the confidence interval

$$(\overline{M} - \underline{M}) = 2\, t_{n-1,\alpha/2} \cdot \frac{s}{\sqrt{n}} \tag{19}$$

of course, is not known. It depends on the value s that is determined by measuring/test. Therefore we cannot determine the required number n of repeated measurements.

The way out of this situation is the following two-step procedure for determining a confidence interval of predetermined length:

1. n_1 repeated measurements of monitored variable X will be realized and then basic statistical indicators of the result will be calculated:

- sample arithmetic average

$$\bar{x}_1 = \frac{1}{n_1}(x_1 + x_2 + \ldots + x_{n1}) \tag{20}$$

and sample standard deviation

$$s_1 = \frac{1}{\sqrt{n_1 - 1}} \cdot \sqrt{\sum_{i=1}^{n}(x_i - \overline{x_1})^2}, \tag{21}$$

2. the length of the confidence interval will be calculated at these values

$$d_1 = \overline{M} - \underline{M} = 2\, s_1 \,.\, t_{n-1,\alpha/2} \,.\, \frac{1}{\sqrt{n_1}} \tag{22}$$

If $d_1 \leq \Delta$, one can proceed as in the case where σ is known with the value s_1 instead of the σ value.

3. If in the second step $d_1 > \Delta$ further n_2 measurements

x_{n1+1} , $x_{n1+2}, \ldots, x_{n1+}\, x_{n1+n2}$ will be realized and one will calculate the new arithmetic mean

$$\bar{x} = \frac{1}{n_1 + n_2}(x_1 + x_2 + \ldots + x_{n1} + x_{n1+1} + x_{n1+n2}), \tag{23}$$

$\bar{x}$ is the sample arithmetic mean of all $n = n_1 + n_2$ measurements.

Confidence interval ($\underline{M}$, $\overline{M}$) shall be determined as

$$\underline{M} = \bar{x} - \Delta, \tag{24}$$

$$\overline{M} = \bar{x} + \Delta, \tag{25}$$

Number of additional needed n_2 measurements is determined so that

$$\sqrt{n_1 + n_2} \geq 2\, t_{n_1 - 1, \alpha/2} \cdot \frac{s_1}{\Delta} \tag{26}$$

CONCLUSION

The current century is predicted to be "The century of quality". Without question the products´ quality improvement demands not only the correct, accurate and fair testing according to the respected international test methods, but also proper using the statistical methods during the assessment of measured results. It is valid fully apart from other things for the products' assessment of conformity/certification, and in the research and development of new material products.

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SENSITIVITY ANALYSIS OF BUILDING STRUCTURES WITHIN THE SCOPE OF ENERGY, ENVIRONMENT AND INVESTMENT

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ABSTRACT

The primary objective of this paper is to prove the feasibility of sensitivity analysis with dominant weight method for structure parts of envelope of buildings inclusive of energy; ecological and financial assessments, and determination of different designs for same structural part via multi-criteria assessment with theoretical example designs ancillary.

Multi-criteria assessment (MCA) of different structural designs or in other word alternatives aims to find the best available alternative. The application of sensitivity analysis technique in this paper bases on dominant weighting method. In this research, to choose the best thermal insulation design in the case of that more than one projection, simultaneously, criteria of total thickness (T); heat transfer coefficient (U) through the cross section; global warming potential (GWP); acid produce (AP); primary energy content (PEI) non renewable and cost per m^2 (C) are investigated for all designs via sensitivity analysis. Three different designs for external wall (over soil) which are convenient with regard to globally suggested energy features for passive house design are investigated through the mentioned six projections. By creating a given set of scenarios; depending upon the importance of each criterion, sensitivity analysis is distributed.

As conclusion, uncertainty in the output of model is attributed to different sources in the model input. In this manner, determination of the best available design is achieved. The original outlook and the outlook afterwards the sensitivity analysis are visualized, that enables easily to choose the optimum design within the scope of verified components.

KEYWORDS

Sensitivity analysis, sustainable design, multi-criteria assessment, envelope structure

INTRODUCTION

Considering the rise in the energy needs of the mankind, it is therefore necessary to balance the energy needs with environmental considerations through innovative and optimum technological ways. In this framework, energy efficiency comes to forefront as one of the key concepts that should be taken into consideration in these endeavors [1].

Good thermal insulation and compactness are key factors to achieve an energy efficient building. The designs cover construction components' energy assessment; ecological assessment and financial assessment.

There is a wide range of construction materials nowadays. The key point is using proper techniques by harmonizing correct practice and materials. Feasibility of the designs based on availability of materials. Therefore all materials used in the designs are accessible and already produced ones.

MCA is a decision-making way via evaluating multiple options that provides the best alternative between conflicting ones. MCA progress deals here within the sphere of environmental issues, energy outlook and investment cost. Dominant weight method-weighting method with implemented sensitivity analysis is used to find the optimum design for each envelope parts of a building. MCA of the different designs based on six criteria - T; U; GWP; AP; PEI and C (based on Turkish construction market prices) simultaneously.

The objective of this study is to find the most convenient design for the same structural place. The unclear qualification of between different designs is solved with sensitivity analysis.

METHODS

In a situation where multiple criteria are involved confusion can arise if a logical, well-structured decision-making process is not followed. Another difficulty in decision making is that reaching a general consensus in a multidisciplinary team can be very difficult to achieve [2].

Under the light of specialized academicians' works, MCA is presented in the form of matrix which works as multiplying alternatives with criteria basically. That identifies the evaluation of each alternative connected to each criterion.

Dominant weight method-weighting method with implemented sensitivity analysis is used to find the optimum design for each envelope parts of a building. MCA of the different designs based on six criteria.

Six different criteria; thickness, heat transfer coefficient, cost, acid produce, primary energy content, global warming potential for three alternative construction types are elements of the sensitivity analysis in the paper. Each criterion has its own vector (d), weight (w) numbers.

Numerically, maximum weight or total weight number is "1" which is top number also for total weight element [Eq. 2]. All numeric values are converted to matrix system due to working system of the calculation. Numeric "vector" values and values of criteria are converted to matrix version called "dominance factor matrix" and "matrix values of the criteria" respectively. Multiplying weight and matrix of vector bring us "extended matrix dominant weights" which is used to calculate "dominance weight matrix" [Eq. 7, 8].

Depending on request or limits or experienced results optimum numbers for each criterion are taken into account and following that "calibrated values of the criteria matrix" is generated [Eq. 3, 5, 6].

To compare different criteria, "weighting matrix criteria" is calculated via calibrated values of the criteria and weights. "Characteristic value of structural alternatives" is calculated by matrix multiplication of weights and matrix values of the criteria [Eq. 1, 4]. Multiplying the calibrated values with weights (matrix multiplication) brings us "weighting matrix criteria" which is the source for visualization of graph of multi-objective sensitivity analysis.

Optimization of component of building structures in terms of environmental issues, energy outlook and cost is the aim of this document following the presented designs. Key component formulas used for calculations are presented below [3]:

Characteristic value of structural alternative as follows:

$$V_{char,i} = \sum_{j=1}^{n} c_{cal\,ij} w_j \qquad (1)$$

Calibration of criteria values as follows:

$$\sum_{j=1}^{n} w_j = 1 \qquad (2)$$

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Optimum (best) value as follows:

$$c_{cal,ij} = c_{ij} / B_{Vj} \tag{3}$$

Matrix of characteristic values of dominant alternatives as follows:

$$[V_{char,ik}] = [c_{cal,ij}][w_{d,jk}] \tag{4}$$

Calibrated matrix of criteria values as follows:

$$[c_{cal,ij}] = [\{c_{cal,i1}\},\{c_{cal,i2}\} \ldots \{c_{cal,in}\}] \tag{5}$$

Calibrated criteria values as follows:

$$\{c_{cal\,ij}\} = \frac{1}{B_{Vj}}\{c_{ij}\} \tag{6}$$

Transformed matrix of dominant weights as follows:

$$[w_{d,jk}] = [\{w_{d,j1}\},\{w_{d,j2}\} \ldots \{w_{d,jn}\}] \tag{7}$$

Dominant weights as follows:

$$w_{d,jk} = \frac{w_j d_{jk}}{1+(D_k-1)w_k}; \quad \sum_{j=1}^{n} w_{d,jk} = 1 \tag{8}$$

Underside of each design comes out of different layers as components of design and each component has different features of energy, environment, and cost matters. In this context, energy and environmental values are based on Austrian Institute for Healthy and Ecological Building (IBO) press [4]. However, numerical values for the cost calculation and energy matters are based on various sources and market research [5-15].

APPLICATION OF DOMINANT WEIGHT METHOD

External Wall Structures

The designed structures' thermal transmittance value vary between 0.105 and 0.113 W/m^{2}K which are lower than the recommended values for Passive Houses by ČSN 73 0540-2 [16]. However, these designs are oriented for theoretical approach. Depending upon feasibility conditions, thickness of the thermal insulation materials may be lowered.

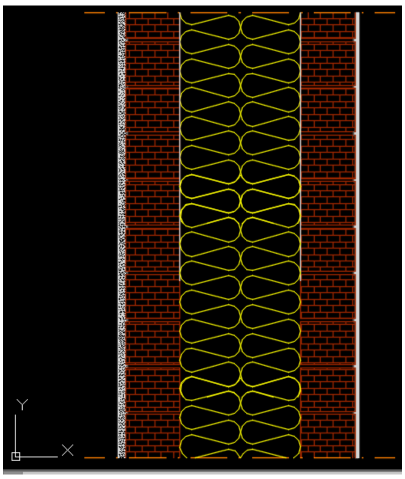

Fig. 1: External wall design 1

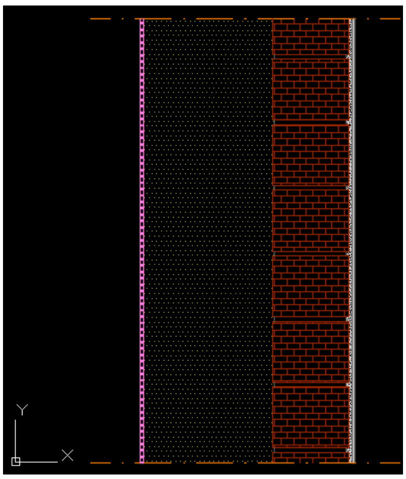

Fig. 2: External wall design 2

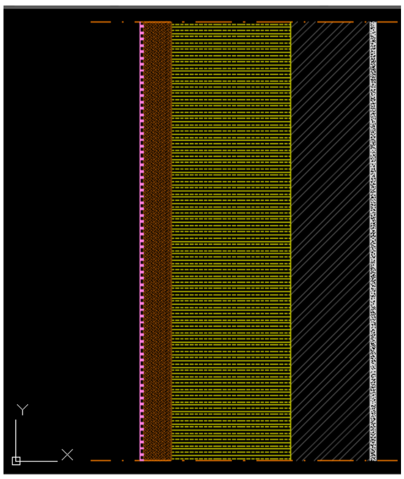

Fig. 3: External wall design 3

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Tab. 1: Components of each design

	Design 1	Design 2	Design 3
Material	Lime Cement Plaster	Silicate plaster	Silicate plaster
	Honeycomb brick (190x190x135 mm)	EPS[1]	Wood wool lightweight panel (cement bound; 2x35 mm board)
	Glass wool	Honeycomb brick (290x235x190 mm)	Mineral wool (between wood C-post)
	Honeycomb brick (190x190x135 mm)	Lime Cement Plaster	Wood chip concrete hollow block masonry
	Gypsum plaster	Gypsum plaster	Lime Cement Plaster

Tab. 2: Vector, weight of each criterion and created dominance factor matrix

Nu	Criterion	Unit	Vector (d)	Weight (w)	Dominance Factor Matrix					
1	Thickness	Mm	1	0.10	1	1	1	1	1	1
2	Heat transfer coefficient	W/m^2K	5	0.25	1	5	1	1	1	1
3	Investment cost	Euro	5	0.25	1	1	5	1	1	1
4	Acid produce	kg SO_2eq/m^2	5	0.05	1	1	1	5	1	1
5	Primary energy content	MJ/m^2	2	0.10	1	1	1	1	2	1
6	Global warming potential	kg CO_2eq/m^2	1	0.25	1	1	1	1	1	1
Total			**18**	**1.00**						

Tab. 3: Extension of dominant weights converted to matrix position

Weight	Extended Dominant Weights					
0.10	0.10	0.10	0.10	0.10	0.10	0.10
0.25	0.25	1.25	0.25	0.25	0.25	0.25
0.25	0.25	0.25	1.25	0.25	0.25	0.25
0.05	0.05	0.05	0.05	0.25	0.05	0.05
0.10	0.10	0.10	0.10	0.10	0.20	0.10
0.25	0.25	0.25	0.25	0.25	0.25	0.25
1.00	**1.00**	**2.00**	**2.00**	**1.20**	**1.10**	**1.00**

[1] EPS: Expanded polystyrene foam.

Tab. 4: Converted dominant weights matrix

Dominant Weights					
0.10	0.05	0.05	0.08	0.09	0.10
0.25	0.63	0.13	0.21	0.23	0.25
0.25	0.13	0.63	0.21	0.23	0.25
0.05	0.03	0.03	0.21	0.05	0.05
0.10	0.05	0.05	0.08	0.18	0.10
0.25	0.13	0.13	0.21	0.23	0.25
1.00	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Tab. 5: Criteria values of different designs

Nu.	Alternative Construction Types	Matrix Values of the Criteria					
1	External Wall 1	600.00	0.108	47.92	0.25041	955.96	402.248
2	External Wall 2	535.00	0.105	34.35	0.27164	1,145.32	296.988
3	External Wall 3	610.00	0.113	72.78	0.70147	1,939.43	127.386
Optimum Values		**500.00**	**0.100**	**50.00**	**0.30000**	**1,500.00**	**300.00**

Tab. 6: Calibration of the criteria values

Nu.	Alternative Construction Types	Calibrated Values of the Criteria Matrix					
1	External Wall 1	1.20	1.08	0.96	0.83	0.64	1.34
2	External Wall 2	1.07	1.05	0.69	0.91	0.76	0.99
3	External Wall 3	1.22	1.13	1.46	2.34	1.29	0.42

Tab. 7: Compare of different criteria

Nu.	Alternative Construction Types	Weighting Matrix Criteria					
1	External Wall 1	0.120	0.270	0.240	0.042	0.064	0.335
2	External Wall 2	0.107	0.263	0.172	0.045	0.076	0.247
3	External Wall 3	0.122	0.283	0.364	0.117	0.129	0.106

Tab. 8: Characteristic value of structural alternative and dominant alternatives

Nu.	Alternative Construction Types	V_{char}	Matrix of Characteristic Values of Dominant Alternatives					
1	External Wall 1	268.18	1.07	1.08	1.01	1.03	1.03	1.07
2	External Wall 2	250.91	0.91	0.98	0.80	0.91	0.90	0.91
3	External Wall 3	305.05	1.12	1.13	1.29	1.32	1.14	1.12

COMMENTARIES

Sensitivity analysis distributed as 40% of environmental performance; 25% economic performance; 25% energy performance and 10% physical feature. Besides that, environmental parameters are divided into three sub-parameters as 5% acid produce; 10% primary energy content and 25% global warming potential. The progress of assigning weights can be iterative.

Under the circumstance of changing the multiplying element-vector factors' values, it has been found that:

Vector factor is not such effective to change the optimal order of thickness criteria. In the case of increasing or decreasing the importance all designs goes closer or further from the centre of the diagram.

Cost of the design is highly sensitive for "external wall 3" design. From the point of cost of investment the design shows disadvantages when the vector value is increased. The other two designs shows opposite behavior which means in the case of high vector value, "external wall 3" goes away from the centre of the diagram and "external wall 1" and "external wall 2" designs come closer to the centre. However, order between "external wall 1" and "external wall 2" designs does not change; in high or low vector values "external wall 2" design seems the most available one.

Heat transfer coefficient and acid produce criteria show very similar behavior as the thickness criteria. However it is clear that the biggest change is visible for "external wall 3" design. In the case of increased vector value "external wall 3" design goes away from the centre of the diagram. Anyway, "external wall 2" design seems as the best one for these criteria for different vector values.

If we increase numeric value of vector factor of primary energy content criterion, there is an interesting progress that "external wall 3" design seems as the last option and beside that, mostly favorite one -"external wall 2" behaves more sensitive than "external wall 3" design. For example, if we set up vector factor as "50"; "external wall 1" design comes closer to the centre than "external wall 2" design. This case is valid only when vector factor is more than "10".

Global warming potential criterion is the most interesting one due to numerical number of the vector. "External wall 3" design is the last case for overall criteria. However, for example, if the numeric value of the vector is "5"; the optimum design is "external wall 3". In the case of this vector value is "1", the optimal order from the best to last be as "external wall 2", "external wall 1" and "external wall 3". We can sum up as that "external wall 3" design is the most sensitive one for this criterion.

In the case of using ineffectual vector factor like "1" for all criteria, the optimal order from the best to last one as "external wall 2", "external wall 1" and "external wall 3" respectively.

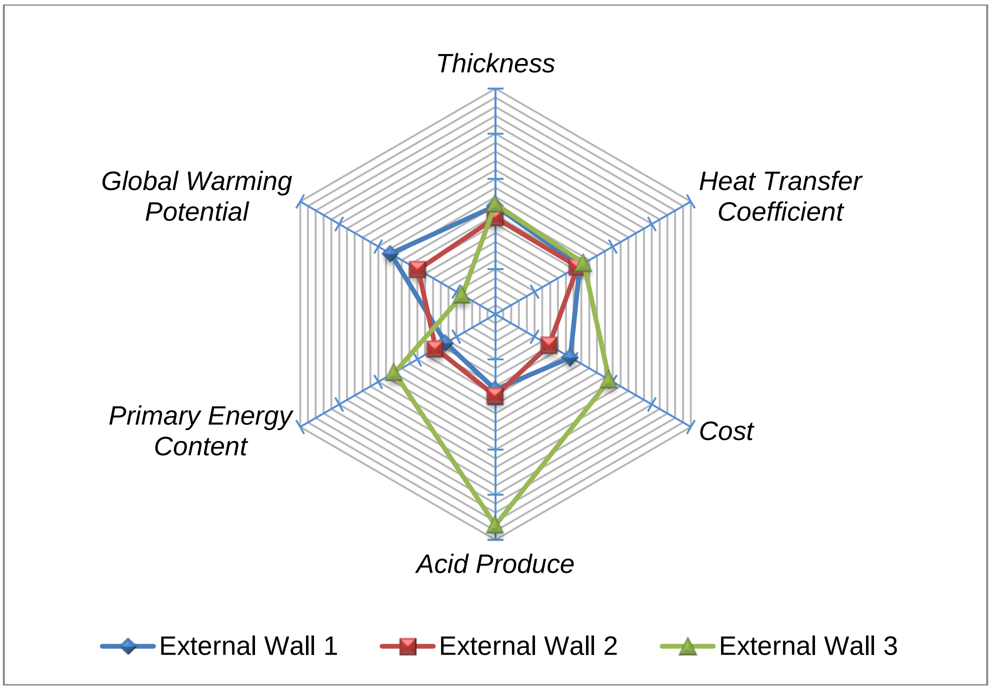

Fig. 4: Comparison of different criteria

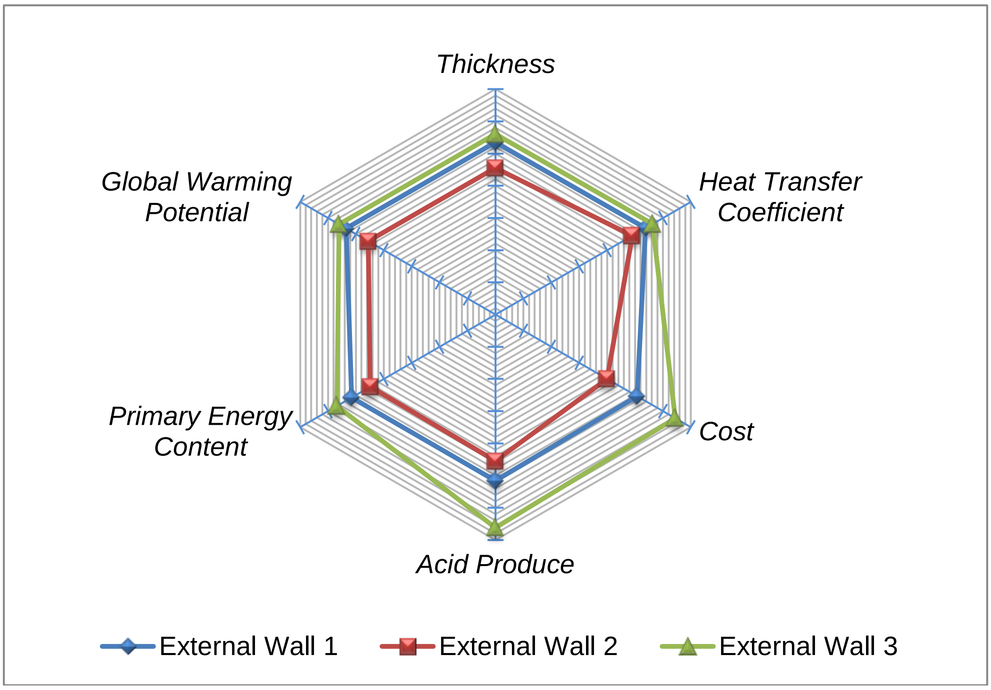

Fig. 5: Multi-objective sensitivity analysis result

CONCLUSION

Sensitivity analysis can be called as “if and what” analysis for many fields. The mentioned analysis in the paper is applied for investigation of building components which consisted of different materials. The purpose of sensitivity analysis is to figure out matters which can influence the decision progress.

The try-out progress of multi-criteria analysis with the sensitivity analysis for different structural layers resulted with concrete result.

The basic principle of the visualized diagram bases on the distance to the centre as means the closer to the core, the better. The elementary condition was unclear for decision progress in the frame of multiple elements (see fig.4) due to different touch points of different criteria to the centre of the diagram. For example, the order starting from the best for global warming potential criteria is wall 3, wall 2 and wall 1 respectively. However, the same order changes as wall 2, wall 1 and wall 3 from the point of cost matter.

Eventually, it was succeed to locate each design with same order (see fig. 5) via the applied method. Therefore, uncertainty is removed for clear decision progress. Regarding to investigation of three different external wall structures; “External Wall 2” design seems as the best available one with the assigned weights. It should be also stressed that number of elements for multi-criteria assessment can be less or more.

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This study avails itself of doctoral thesis with title “Buildings with Low Energy Consumption for the Republic of Turkey” (2015) of Ing. Kağan Poyraz, Ph.D. with the supervision of Doc.Ing. František Kulhánek, CSc. at Czech Technical University in Prague.

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DEFECTS AND FAILURES OF JOINTS OF HISTORIC ROOF TRUSSES AND POSSIBILITIES OF USING FRP MATERIALS IN THEIR REHABILITATION AND STABILIZATION

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ABSTRACT

The survey of selected historic roof trusses performed within the NAKI DF12P01OVV037project revealed numerous failures and defects of joints of roof truss elements of historic and listed buildings. Based on the results of the survey, the article outlines potential rehabilitation and reinforcement techniques of joints of roof truss elements in which the most frequent defects and failures were found using composite fabrics based on high-strength carbon fibres and epoxy resin (CFRP).

KEYWORDS

historic roof trusses, rehabilitation, stabilization, high-strength carbon fibres

STRENGTHENING OF TIMBER CONSTRUCTION WITH FRP MATERIALS

Composites based on high-strength fibres and epoxy resin are currently most commonly used for strengthening beams in timber structures. The bulk of scientific studies carried out since the second half of the 1960s has focused on the application of these materials for strengthening timber elements under flexural loading or for their local reinforcement under shear loading or increasing locally their tensile/compressive strength in bending [2, 3, 4, 7, 9, 10, 11, 12]. The research manifested that even low level reinforcement with high-strength fibres leads to a significant increase in the load-bearing capacity and rigidity of a timber element. According to Andre [1], reinforcing fabrics have a prominent effect on enhancing the resistance of dynamically loaded structures. Research into the strengthening of historic timber beams with carbon strips [8] pointed out the fact that the preparation of the surface for gluing had an important role in the mutual interaction of wood and the carbon strip. The strengthening of carpentry joints of wooden elements with composite materials has been outside the main stream of research so far; the preferred procedures are mostly based on cutting holes or grooves for mounting composite rods. The issues of strengthening timber joints with metal connectors by means of technical textiles were investigated by [5]. The behaviour of joints of historic structures was analysed and their rehabilitation solved by [6]. The design procedures and the assessment of structures - elements and joints - reinforced with composite materials based on high-strength fibres and epoxy resin have not been integrated into technical standards yet.

STRUCTURAL DESIGN OF ROOF TRUSSES, THEIR MOST FREQUENT DEFECTS AND FAILURES

Roof trusses belong to outstanding technical and construction monuments documenting the high workmanship level of builders of the past and representing, in many cases, complex spatial constructions. While evaluating the structural function of individual elements of historic roofs it is often not easy to determine the function of some roof truss elements in connection with the overall design of the roof truss and its joints. The oldest historic trusses were designed based on the intuition and experience of builders and carpenters of that time.

The structural design of roofs has created a series of unique roof truss constructions over the historical evolution of architectural styles and construction practices differing mainly by the type of supporting rafters and securing the transfer of the effects of vertical and horizontal loads into the masonry structure. The basic roof truss systems with a number of transitional versions are a rafter system, strutting beam system, and purlin system.

The joints of individual elements of trusses are crucial for their mutual interaction, for securing the structural function, spatial rigidity and dimensional stability of roof trusses. The most commonly used carpentry joints of wood trusses (scarf joints and lap joints, halving joints, mortise and tenon joints, single or multiple dovetail joints, bird's mouth joints and cogged joints complemented by wooden pegs, corner beads, iron angles and special elements, nail or bolt connections) may be classified as non-rigid, yielding joints, considered as articulated joints if the appropriate adjustment prevents the displacement of an element in the joint. In cases where it cannot be reliably assumed that there is no displacement in the joint, the joint is considered as simply supported (running in a straight line in the direction of the anticipated displacement - so-called "linear joint"). Articulated joints of roof truss elements – e.g. rafters at the apex, a strut and a strutting beam, a strutting beam and a rafter, etc. - complemented by a brace in the immediate vicinity already have a nature of an unyielding joint in bending, which can be classified as a rigid joint. The spatial rigidity of the roof truss construction in the longitudinal direction generally depends on the mutual connection (coupling) of principal or common rafters. In roof truss systems with standing or lying trusses, braces, struts, seats, St Andrew's crosses, etc. the above elements secure the distribution of the horizontal load onto individual roof trusses in the proportion to their rigidity.

SURVEY OF SELECTED ROOF TRUSSES OF HISTORIC BUILDINGS

The NAKI DF12P01OVV037 research project included the visual survey of roof trusses of selected historic buildings of the Premonstrate Monastery at Teplá (Fig. 1a), Hájčí Court in Prague (Fig.1b), a sheep shed of Lužany Castle (Fig. 1c) and Litovice Stronghold (Fig. 1d). The historic masonry buildings selected for the survey come from different regions of the Czech Republic differing by their type of use, maintenance quality or rehabilitation measures performed (protection against biological degradation).

Due to the fact that the issues of strengthening timber elements, mainly beams, with composite materials based on high-strength fibres and epoxy resin are the subject of long-term research, the survey of the above structures was primarily focused on the defects and failures of joints of truss elements with the objective of verifying the applicability of composite materials for their rehabilitation and strengthening.

The survey dealt with the frequency of the failures of carpentry joints used in the roof truss construction (100% = total number of a respective type of carpentry joint in the construction). Tab. 1 to Tab 4 present relative proportions [%] of the above carpentry joints revealed during the visual survey of defects and failures, e.g. slippage of an element from a joint, pin deformation, etc.

Tab. 1 Roof truss survey evaluation – frequency of failures – Premonstrate Monastery at Teplá

CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS
Miltre joint	2%	Butt joints	35%	Tenon joints	55%
Halving joints	2%	Dado joints	45%	Bird´s mouth joints	25%
Cogged joints	15%				

Tab. 2 Roof truss survey evaluation – frequency of failures – Hájčí Court

CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS
Miltre joint	5%	Butt joints	45%	Tenon joints	60%
Halving joints	4%	Dado joints	55%	Bird´s mouth joints	30%
Cogged joints	10%				

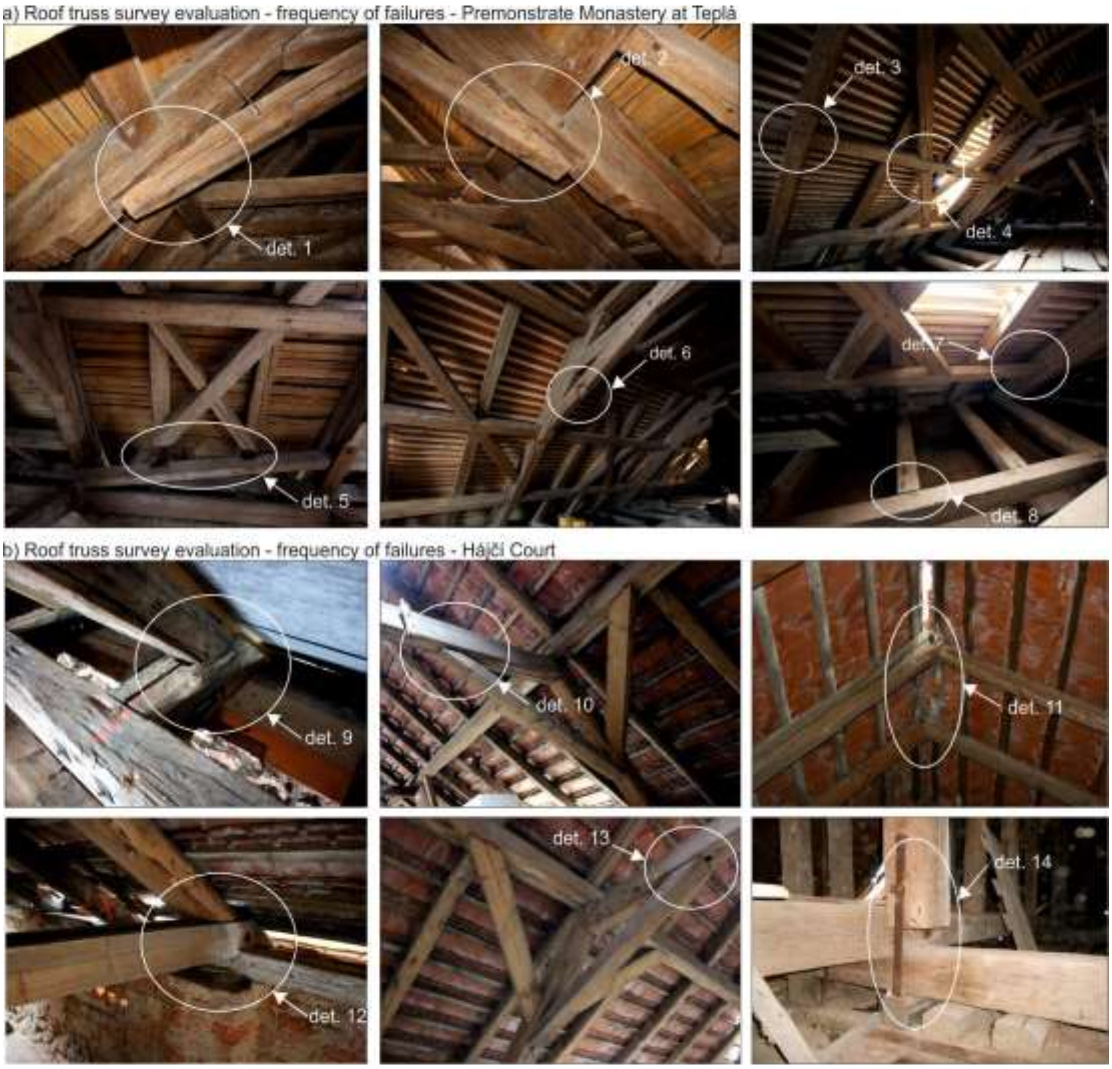

Fig 1. Roof truss survey evaluation – frequency of failures

Tab. 3 Roof truss survey evaluation – frequency of failures – Lužany sheep shed

CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS
Miltre joint	3%	Butt joints	45%	Tenon joints	60%
Halving joints	10%	Dado joints	65%	Bird´s mouth joints	25%
Cogged joints	15%				

Tab. 4 Roof truss survey evaluation – frequency of failures – Litovice Stronghold

CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS	CARPENTRY JOINTS	THE HIGHEST FREQUENCY OF DEFECTS
Miltre joint	8%	Butt joints	48%	Tenon joints	60%
Halving joints	1%	Dado joints	36%	Bird´s mouth joints	45%
Cogged joints	20%				

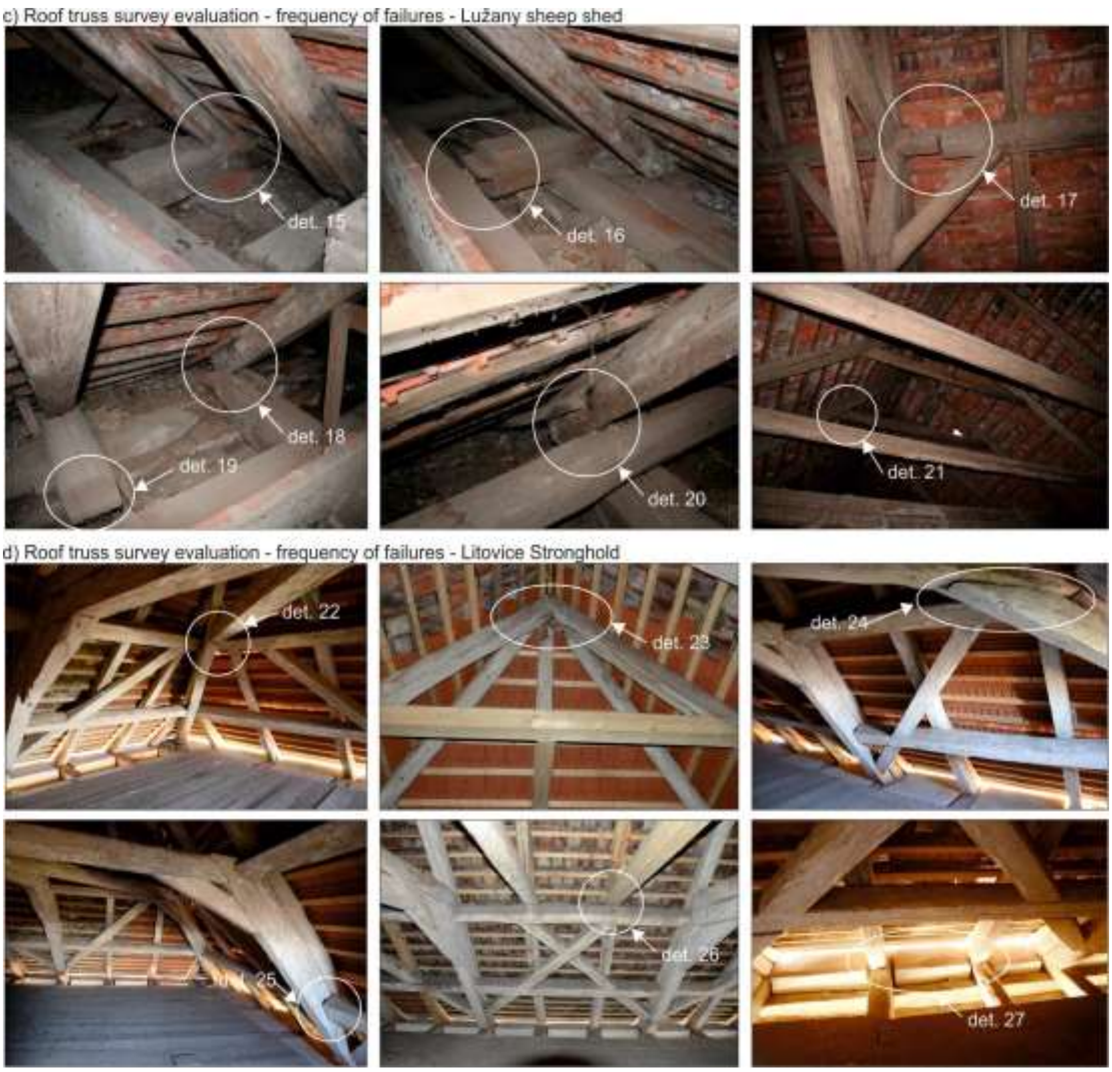

Fig 2. Roof truss survey evaluation – frequency of failures

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The evaluation of the visual survey of roof trusses of selected historic buildings pointed out that the highest frequency of defects and failures have been found in the following carpentry joints: dado 36 – 60% of degraded joints, bird's mouth 25 – 45% of degraded joints, mortise and tenon 55 – 60% of degraded joints and butt 35 – 45% of degraded joints.

In bird's mouth joints, non-precise shaping of the "cog" appeared most frequently, its excessive length and different planeness of contact surfaces (the element does not fit in the entire area of the joint). In the case of mortise and tenon joints, the most common failure was partial or total slippage of the tenon from the mortise, tenon deformation or large tolerances and the ability of tenon "movement" in the mortise. In the case of butt joints, the most frequently occurring defect was different planeness of contact surfaces, in dado joints large tolerances and also different quality of the bearing surfaces. Some of the above defects are, to some extent, affected by volume changes of wood. Based on the survey of selected historic buildings, we may summarize that the most common defects of selected historical roof trusses from the perspective of joints of truss elements are poor quality or loosened joints, their insufficient rigidity and bearing capacity, inappropriate joint design, insufficient spatial rigidity of the truss system in the transverse and longitudinal direction (faulty, loosened connections). The most common failures of joints according to the research are the loosening or damage of joints, loosening of nails, bolts, loosening of carpentry joints, etc., nail corrosion in wood (using wet thin wood), loosening of anchoring iron ties (straps) of eaves plates, excessive deformations of the roof truss due to insufficient rigidity of principal trusses or loose or unsecured joints, degradation of the roof truss due to unqualified interventions (removal or damage of e.g. tie beams, purlin posts, etc.), initial deformations of built-in elements or their excessive shrinkage. The prevailing part of the above failures is caused by the properties of wood (shrinkage or swelling, biological degradation, poor quality of wood), while failures caused by the overloading of the construction, excessive deformations or insufficient dimensions of some elements are represented to a lesser extent.

REHABILITATION AND STRENGTHENING OF SELECTED JOINTS OF TIMBER ROOD TRUSS ELEMENTS

To ensure a long service life and functional reliability of historic roofs we must, above all, provide conditions that minimize the risk of biological degradation of wooden elements and their joints i.e. prevent the penetration of elevated moisture levels into the roof truss construction. At the same time, it is also necessary to secure sufficient strength and rigidity of the roof truss construction, both of its individual elements and their joints. The methods used presently for the rehabilitation of joints and increasing their load bearing capacity are invasive methods (e.g. inserting steel plates and bolts). They reduce, to some extent, the historical value of the roof truss and are not reversible (Fig. 2).

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Fig 3. Traditional strengthening and stiffening of joints of roof truss members – using steel bolts and plates

The application of composites based on high-strength fibres and epoxy resin for the rehabilitation and strengthening of joints of roof truss members is advisable in terms of the minimum additional loading of the construction and the minimum dimensional changes of the connected elements. Fig.3 shows reinforcement and bracing options for the most frequently damaged joints of roof truss elements selected on the basis of the survey. Apart from the low weight and width (thickness) of the reinforcing layer of a composite based on high-strength fibres and epoxy resin, another important characteristic, from the perspective of current heritage conservation, is the non-invasiveness of these materials in surface applications and a possibility of their later removal.

The proposed rehabilitation and strengthening techniques of joints of timber truss elements are designed for surface applications of composite strips of fabrics of high-strength fibres and epoxy resin: surface applications reduce further weakening of stressed joints which would otherwise require the execution of holes or grooves for inserting bars or lamellae. The disadvantage of surface reinforcement is the necessity of ensuring adequate anchorage lengths of reinforcing strips and the necessity of previous surface treatment of wooden elements to secure the highest quality of the contact between the reinforcing layer and the elements of the reinforced joint.

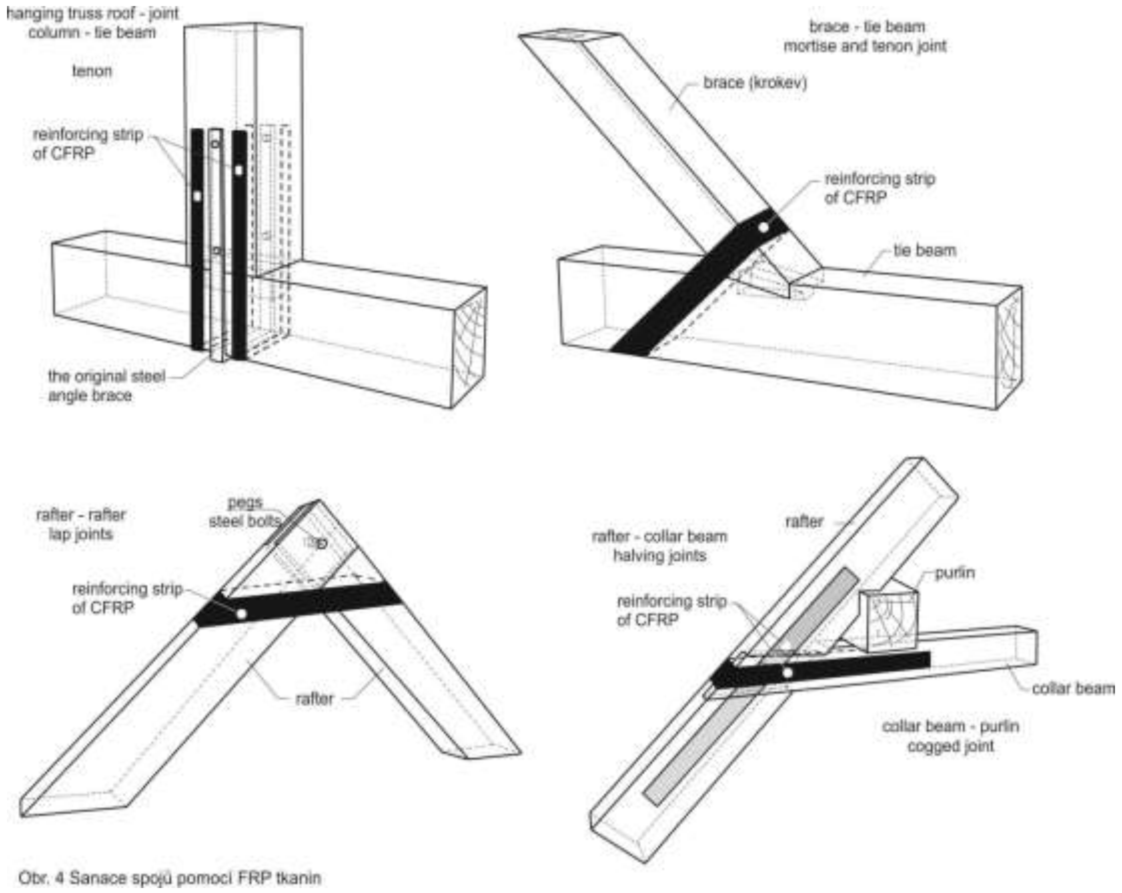

Fig 4. Rehabilitation of selected joints by means of surface application of CFRP composite fabrics and epoxy resin

The disadvantage of surface applications is the high diffusion resistance of the composite. The prevention or limitation of natural drying (non-uniform shrinkage) of parts of the element around the joint may set off the development of biodegradation processes and subsequent destruction of parts or entire roof truss elements. For this reason, the reinforcement of joints should not be carried out on the overall surface basis, but should be limited to strips with a required width. For the above reasons, but also to protect wood, it is necessary to minimize or completely eliminate the sources of moisture (leakage, condensation, capillary action, etc.), especially in places of the masonry contact with wood.

The application of a composite based on high-strength fibres and epoxy resin is also limited by the low fire resistance of this material, where most epoxy resins already start melting at 80 °C and the reinforcement loses its structural effectiveness. For this reason, the completed reinforcement must be properly protected from the effects of high temperatures.

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CONCLUSION

The above survey has manifested that regardless of the locality where a building is situated and the building's purpose, the carpentry joints with the most frequent occurrence of defects and failures are butt joints, dado joints, bird's mouth joints and mortise and tenon joints. On average, 40 – 50% of these joints currently show some defect or failure.

The application of composites based on high-strength fibres and epoxy resin is a non-invasive, reversible rehabilitation option for joints of roof truss elements. It is a surface application using strips of fabrics based on high-strength fibres applied onto clean and solid wood surfaces which may be completely removed without any major consequences in the future and replaced with a new technology. The possibility of using composites based on high-strength fibres and epoxy resin for the reinforcement of carpentry joints is a progressive technique, which, however, requires the performance of comprehensive experimental and theoretical research to identify the design and calculation procedures.

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POTENTIAL APPLICATIONS OF TRANSPARENT FABRIC BASED ON NANOFIBRES FOR THE STRENGTHENING OF PLASTERS DECORATED WITH PAINTINGS AND FRESCOES

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ABSTRACT

Nanomaterials have been increasingly used in the construction industry in the last decades. Nanomaterials have been tested in specific applications focusing on the restoration and conservation of heritage buildings, mainly their surfaces. Nanofibre materials represent a separate area within this field of research and their applications in the construction and conservation practice are still very limited. The article summarizes the possibilities of strengthening plasters decorated with wall paintings with nanomaterials.

KEYWORDS

Nanotextiles, plasters, paintings, degradation

INTRODUCTION

The surface treatment of buildings, both in the exterior and interior, is an integral part of their appearance and value (Fig.1). Apart from the technical importance of protecting the building and its surface, this treatment has always had an aesthetic function subject to changing trends. In all historical periods, surface coatings have participated in creating the building's appearance adding the final touch to it and improving its surface.

Historical plaster represents a tangible proof of craftsmanship, the degree of technical skills and creates a credible and coherent final appearance of plastered historic buildings. The preservation of historic coatings, plasters or plasters decorated with wall paintings belongs to key issues of top quality heritage conservation. The appearance of each building results from the combination of many components, e.g. the application method, surface treatment, grain size, colour, and, last but not least, the artistic impact, etc. [6]. Numerous techniques of mural painting have developed over the centuries; they can be divided into two basic groups according to the nature of the substrate: paintings on dry plaster and paintings on fresh i.e. wet plaster. According to the type of technique selected for mural painting (buon fresco, secco, Kalkmalerei, tempera, oil, etc.), the required plaster treatment was performed. In the case of mural painting, the readiness and type of the substrate for painting is quite significant – a normal fresh plaster substrate coated with so-called intonaco (final, very thin layer made of a mixture of plaster and fine sand or ground marble dust) sufficed for the traditional, so-called classic, fresco technique, but for the tempera technique the wall had to be previously coated with white pasty sealant (with a spatula) made from e.g. washed chalk or ground gypsum (so-called gesso).

Fig. 1: Bečov Castle – authenticity of plaster surfaces: a)southern facade, b) the Annunciation Chapel, c) corner room in the donjon) stress the genuine historical appearance of buildings

Before taking any preservation or restoration steps, however, detailed historical, construction and technical, conservation and other surveys of plasters and related structures must be done. Based on the results of the surveys, a suitable procedure is selected for the damaged historical surface restoration. The conservation of historic plasters is an interdisciplinary branch combining the expertise of specialists from among architects, designers, heritage preservation specialists, heritage technologists, restorers and, last but not least, craftsmen who perform the restoration [13]. At this point, it must be noted that the restoration of multi-layer plasters should be preceded by the restoration of the historic structure as a whole.

The conservation and restoration of plasters decorated with wall paintings include the performance of many procedures, such as, for example, the consolidation, cleaning, removal of accessories and retouching, cementing, new retouching and others. The application of nanomaterials in some of the above procedures belongs to advanced technologies that are slowly gaining ground in building construction as well. Nanomaterials are made up of a cluster of several thousand atoms and exhibit properties somewhere at the intersection between properties at the level of molecules and matter [1, 8]. This characteristic results from the high surface area of their clusters, which significantly affects the physical and mechanical properties of these systems. Among the benefits obtained from the material nanostructure, there is, for example, high chemical performance, superior plastic, consolidation and diffusion properties, low sintering temperature, cleaning capabilities, etc. It is, therefore, easy to understand that these innovative materials are the subject of major research interest.

It may be assumed and has been confirmed by the research conducted to-date, e.g. in Italy, that applications of nanotechnology in the restoration and preservation of historic plaster surfaces decorated with mural paintings belong to progressive conservation procedures [2, 3, 5]. The used and presently verified technologies for reinforcing plasters include mainly nanosuspensions containing calcium hydroxide nanoparticles and nanomaterials based on barium hydroxide or sulphates [7]. The active substances are dispersed in alcohols, which is also advisable in the technological perspective, as, first, there is no repetitive wetting of surfaces with water, and secondly, their application in relation to the risk of their freezing is not limited. Among the currently already commercially available products there is so-called nanolime - nanosuspension with the trade name “CaLoSil” (in Germany) or Nanorestore (in Italy), which is mainly used for the consolidation of materials containing calcium carbonate (e.g. arenaceous marl, limestone, lime plasters) [11, 12]. The particle size of calcium hydroxide in this nanosuspension ranges from 50 to

200 nm, which creates a limitation in relation to the pore size of the treated material. An indisputable advantage is a significant reduction in impregnation cycles - several applications of nanolime ensures reinforcement which may only be reached after thousands of cycles when using lime water. Nanolime may also be advisably used for the removal of mould, realkalisation of paper, coatings, adhesives, surface layers, preservation of wood, etc.

The success of the consolidation process using nanomaterials is affected by the mineralogical and chemical composition of the treated material, the characteristics of the pore system, surface structure, degree of hardening before the treatment, properties of the active substance in the reinforcing agent (size of ions and particles, chemical composition, concentration, drying and hardening rate, etc.), and, finally, by the temperature and moisture conditions during the application.

Compared to nanosuspensions, nanoemulsions and nanogels, the consolidation of surfaces of historic buildings, mainly plasters or plasters decorated by wall paintings, based on the application of nanotextiles produced by electrospinning falls behind as an unverified technique. Nanotextile is a non-woven fabric, formed by chaotic lying of ultrafine fibres on a flat textile substrate (so-called spunbond) or directly on the surface of the treated material. The best choices for the production of nanofibres are fibre-forming materials, such as polymers and carbon fibres [16]. Nanotextile properties can be further improved by means of additives, e.g. some metals. The application of this composite structure can e.g. enhance the resistance of surfaces against aggressive components of the environment (e.g. bacteria) or their self-cleaning capabilities [4, 14, 15].

MATERIALS AND METHODS

Extensive experimental research is currently running at the Faculty of Civil Engineering CTU in Prague within the NAKI project addressing the possibilities of the consolidation, stabilisation and cleaning of plastered surfaces by means of nanotextiles. The research aims to verify the applicability of nanotextiles and the effectiveness of selected PVB and Paraloid B72 nanotextiles without dopants and PVB and Paraloid B72 nanotextiles doped with Ag and TiO2 nanoparticles. The research is carried out in the laboratories of the Faculty of Civil Engineering CTU and under in-situ conditions in an agricultural building of the Premonstrate Monastery complex at Teplá.

The specimens of all the above mentioned nanotextiles were prepared in the laboratory of the Pardan Company on the FE production line using the forcespinning technology.

PVB without admixtures was electrospun using the standard forcespinning technology process. In cooperation with the Nanotrade Company, a spinning solution was prepared containing 100mh.ppm of Ag nanoparticles 40-50nm in size, the resulting nanofibre layer has a basis weight of 1.6 g/m^2. To produce nanofibres with TiO2 dopants, a 5% Degussa Aeroxid P25 solution was prepared using the Schwego ultrasonic dispergator, the resulting nanofibre layer has a basis weight of 1.6 g/m^2.

The production process was further modified to electrospin Paraloid B72 where 14.5 g/m^2 of nanofibres had to be applied to create a solid peelable layer. Ag and TiO2 dopants were additionally applied onto the Paraloid B72 nanofibre layer with a manual sprayer. In the case of Ag nanoparticles, 588 ppm of Ag were applied onto the nanofibre layer with a basis weight of 10 g/m^2. The mean concentration of TiO2 nanoparticles corresponds to 2% of dry matter (polymer and binder) of the nanofibre layer with a basis weight of 10 g/m^2.

PVB and Paraloid B72 nanotextiles without dopants, the PVB nanotextile with Ag or TiO2 dopants and the Paraloid B72 nanotextile doped with TiO2 have light, milky colour. The exception is electrospun Paraloid B72 doped with Ag, which has light, yellow-brown colour and is very brittle (Fig.2).

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Fig. 2: a) Paraloid B72 nanotextile doped with TiO2, b) Paraloid B72 doped with Ag

The plaster samples were prepared 100mm in diameter and 15 mm in thickness to verify the possibility of using nanotextiles for the stabilisation of surfaces treated with colour paint. The plaster composition formula was designed based on the laboratory analysis of a historic Renaissance plaster: 5 kg of dry hydrated lime, 10 kg of river sand - fraction 0-2 mm, 3 litres of water (= dry mixture composition). After drying, the surfaces of the samples were wetted with lime water the day before and immediately before the application and natural colour pigments diluted in water in the shade of blue and ochre by the Picasa Company were applied onto them. Based on the previous testing of adhesives [9, 10, 17], nanotextile specimens were applied onto the lime plaster samples using acetone, ethanol and lime water at a surface temperature of 23° C and a relative humidity of 52%.

Before the nanotextile was applied on the plaster, its surface had been wetted with corresponding solvents and individual nanotextiles on the spunbond were successively applied onto the plaster surface (PVB without nanoparticles, PVB with Ag and TiO2 nanoparticles, Paraloid B72 without nanoparticles, Paraloid B72 with Ag and TiO2 nanopaticles). The spunbond was easily removed after the application of the nanotextiles on the coloured surface of the historical plaster.

Subjective evaluation of the effectiveness of the nanomaterial application was performed by simple tests directly on the surface of the samples - visual assessment, the indentation test and the estimate of the depth of consolidant's penetration. In the case of applications by means of acetone and ethanol in laboratory conditions, nanotextiles are not visible on the plaster surface. The plaster surface remains unchanged and no whitish haze is created on its surface. As a result of the dissolution of nanotextiles, surface penetration of the material into the plaster sample occurred. Visible changes are apparent only in cases where lime water was used as an adhesive. In these cases, the nanotextile poorly adheres to the surface of the plaster; it does not exhibit the necessary cohesiveness and falls off.

The nanotextile's integration into the plaster structure is unsatisfactory in some cases. In the case of PVB applications using limewater, the nanotextile's application onto the specimen failed, and in eight cases the nanotextiles dissolved. In nine cases, the nanotextile is visible on the surface, but does not exhibit the required cohesiveness, it peels off, the surface is slightly whitish or the nanotextile is not completely dissolved and remains on the surface of the sample. These problems occur in particular in the case of the electrospun PVB polymer with lime water, PVB with TiO2 dopants with acetone and lime water, PVB with Ag dopants with lime water, then in the electrospun Paraloid B72 acrylic resin with lime water, Paraloid B72 with TiO2 dopants with acetone and lime water and Paraloid B72 with Ag dopants with acetone, ethanol and lime water. Satisfactory results in terms of application include PVB nanotextiles with acetone and ethanol, PVB with TiO2 dopants

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with ethanol, PVB with Ag dopants with acetone and ethanol, Paraloid B72 with acetone and ethanol and Paraloid B72 with TiO2 dopants with ethanol. In these samples, the nanotextiles interlocked with the surface structure of the plaster and there was no discolouration.

CONCLUSION

Based on the results of laboratory tests, we may summarize that working with nanotextiles does not seem promising in applications on historical material or any mature construction material. The application itself remains the fundamental problem: the nanotextile dissolves if an adhesive (acetone, ethanol) is used. In the case of applications using lime water, the adhesion of the nanotextile to the substrate could not be secured – it remained tightly stretched over protruding uneven parts and, therefore, not integrated into the plaster structure. Another problem is the depth of its effectiveness – the nanotextiles remain in layers close to the surface or on the surface. Their effectiveness in relation to the consolidation of historical material is, therefore, negligible or none at all.

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