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RECTIFICATION OF THE CHURCH BUILDING IN BYTOM MIECHOWICE AND THE RESULTS OF LASER SCANNING 3D

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Abstract

Rectification of a structure, it's a kind of its rotation and offset (translation) in the desired direction to place it in a proper location of space. The rectification method in Poland is proven in over 500 cases and uses several dozen hydraulic jacks placed in recesses of foundation walls in the building. Rectification process is controlled by computer.

The paper presents the rectification process of the church building situated in Mother Eve Street in Miechowice district of Bytom. This structure is made of bricks and partial basement with the layout of two naves. The building church was built in neo-Gothic style in 1896. Underground mining extraction has been carried out nearby the object since the 1930s. The coal seams were extracted directly beneath the structure in the years 2008–2012. The results of the mining operations were damages of the church building such as numerous cracks in walls and in vaults. After mining extraction the building block had been deflected of 30 mm/m. The article presents the measurement method of building deflection and includes description of caused cracks before and after rectification process. The block of the church building was measured before and after rectification using the laser scanner 3D Trimble TX5. The point cloud was used to create a 3D model of the object as visualization after capturing and processing data. The completed measurement is the example of the usage of laser scanning 3D as a new tool that enables a user to gain the 3D information of an object in the interest.

REKTYFIKACJA KOŚCIOŁA W BYTOMIU MIECHOWICACH I WYNIKI SKANOWANIA LASEROWEGO 3D

Słowa kluczowe: eksploatacja górnicza, pochylenie, skanowanie laserowe, rektyfikacja

Abstrakt

Rektyfikacja obiektu budowlanego to jego obrót (rotacja) oraz przesunięcie (translacja) w żądanym kierunku tak, aby zajął on prawidłowe usytuowanie w przestrzeni. Sprawdzona w ponad 500 przypadkach metoda, polega na użyciu układu kilkudziesięciu podnośników ulokowanych we wnękach ścian fundamentowych budowli. Proces rektyfikacji jest sterowany komputerowo.

W artykule przedstawiono proces rektyfikacji kościoła przy ul. Matki Ewy w Bytomiu Miechowicach. Jest to obiekt murowany z cegły, o układzie dwunawowym, częściowo podpiwniczony, który wzniesiono w stylu neogotyckim w roku 1896. Eksploatacje górnicze, które oddziaływały na obiekt, prowadzono od lat 30. XX wieku, ostatnie prace – prowadzone bezpośrednio pod nim – miały miejsce w latach 2008–2012. Skutkiem dokonanej eksploatacji były uszkodzenia budowli objawiające się licznymi pęknięciami ścian i sklepień oraz pochyleniem bryły rzędu 30 mm/m. Opisano metodę pomiaru pochylenia budowli i rejestracji pęknięć przed procesem rektyfikacji oraz po jego zakończeniu. Przeprowadzono pomiary budynku kościoła przed i po rektyfikacji, przy wykorzystaniu skanera laserowego 3D Trimble TX5. Uzyskiwane z pomiarów chmury punktów posłużyły do opracowania modelu 3D obiektu. Zrealizowane pomiary stanowią przykład wykorzystania nowego narzędzia, jakim jest skanowanie laserowe 3D do rejestrowania, przetwarzania i wizualizacji informacji 3D o obiekcie.

1. INTRODUCTION

Underground mining extractions usually causes continuous surface deformations. The following have the greatest impact on buildings located in mining areas: horizontal deformation ε, depression *w,* inclination *T* and curvature *K*. In the case of public and residential buildings the research has shown (Kawulok 2000, Kwiatek 1997) that vertical declination which equals 15÷25 mm/m is cumbersome and vertical declination above 25 mm/m is inadmissible. Such declination should be removed, which means the object is should be rectificated.

Two methods of rectification can be distinguished; first one involves removing the soil under the object's part which is located higher, second one involves lifting the part which is located lower with hydraulic jacks (Gromysz, Niemiec 2010).

The usual method of rectification used for leaning objects is uneven lifting them by using several hydraulic jacks built into the walls of the basement of the building (Gromysz 2015). With this method the MPL company has delivered over 500 rectifications of various buildings, including single-family and multi-family houses (five and eleven-storey ones) and three churches.

2. BUILDING RECTIFICATION PROCESS WITH HYDRAULIC JACKS

Rectification process which involves using hydraulic jacks consists of three phases (fig. 1) (Gromysz, Niemiec 2010). First phase is to let the building to burst – as a result horizontal gap between jacks is created. For buildings with reinforced concrete walls the course of the gap is determined by design solutions (a combination of prefabricated elements or – in case of monolithic structure – intersection where reinforcement has been dissected). In brick constructions the gap runs under the build-in wall reinforcement. The gap creation is stimulated by sequential forcing displacement in each jack.

Second phase involves parallel lifting (translation). All jacks sidle out on the same height so the building is lifting 20–30 mm. This is necessary so in the next stage the edges of the rotating part of the building are not catching on the parts remaining in the ground.

Third phase is reduced to lift the building up unevenly, namely rotation around the axe beyond the outline of the foundation and perpendicular to inclination vector of the building.

Every object designed for rectification requires a number of preparatory treatments, including forging niches for jacks, doing necessary reinforcements and placing jacks in niches. It is also required to temporarily cut off some installations such as central heating, gas, water and sewage.

3. PREPARING THE CHURCH BUILDING FOR RECTIFICATION

The church is a part of historic complex of buildings from the late XIX century. Small church was built in neo-gothic style in 1896 (fig. 2). It was made from bricks, has two naves layout and partial basement. Aisle is situated on the north side.

Apart from significant inclination, church's design elements are damaged – many wall and vault cracks 15 mm width can be observed (Gromysz 2015). Because

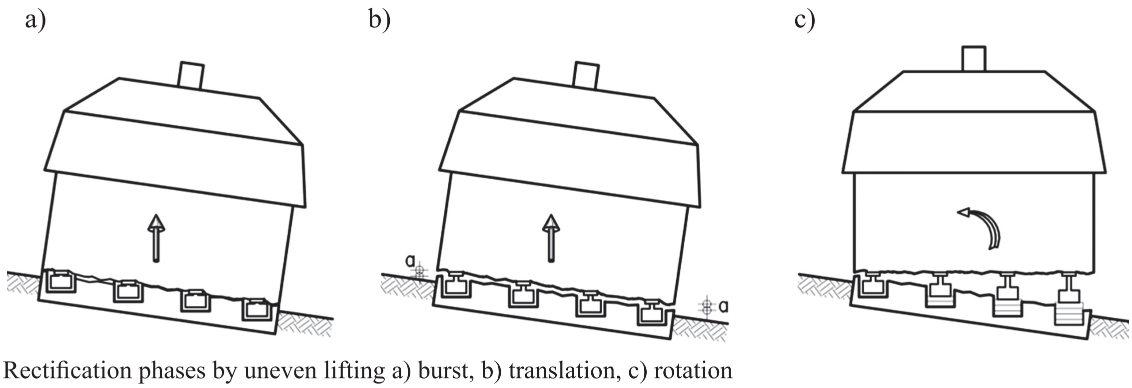


Fig. 1. Rectification phases by uneven lifting a) burst, b) translation, c) rotation

Rys. 1.. Fazy rektyfikacji przez nierównomierne podnoszenie a) rozerwanie, b) translacja, c) rotacja of these cracks construction supervision has excluded the object from the use. Since 1987, the church is subject to the supervision of the conservator. For this reason, all works related to the rectification were planned below ground level.

Temporary steel reinforcement was built inside of the church's building while rectification works were in progress. It is made of channel section 160 connected to the walls with steel bolts. Reinforcement method has been introduced on below drawings and photos.

Fig. 2. General view of the church's body (information about church, wikipedia)
Rys. 2. Widok ogólny budowli kościoła (informacja o kościele, wikipedia)

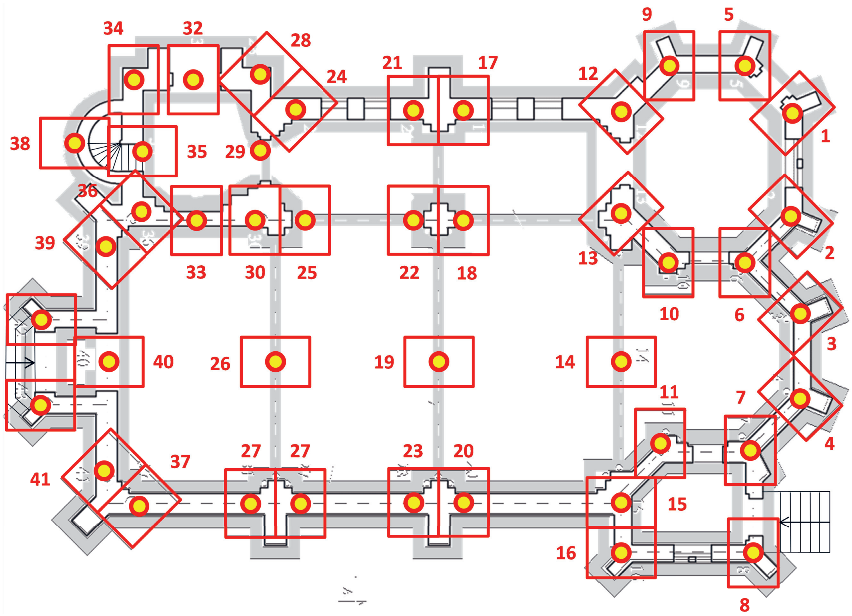


Fig. 3. Steel reinforcement of church's walls and jack's configuration chart
Rys. 3. Wzmocnienie ścian kościoła konstrukcją stalową i schemat rozmieszczenia podnośników

Fig. 4. Flooring reinforcement set up for the duration of rectification
Rys. 4. Wzmocnienie budowli w poziomie posadzek na czas rektyfikacji

Fig. 5. Vault reinforcement set up for the duration of rectification
Rys. 5. Wzmocnienie budowli w poziomie sklepienia na czas rektyfikacji

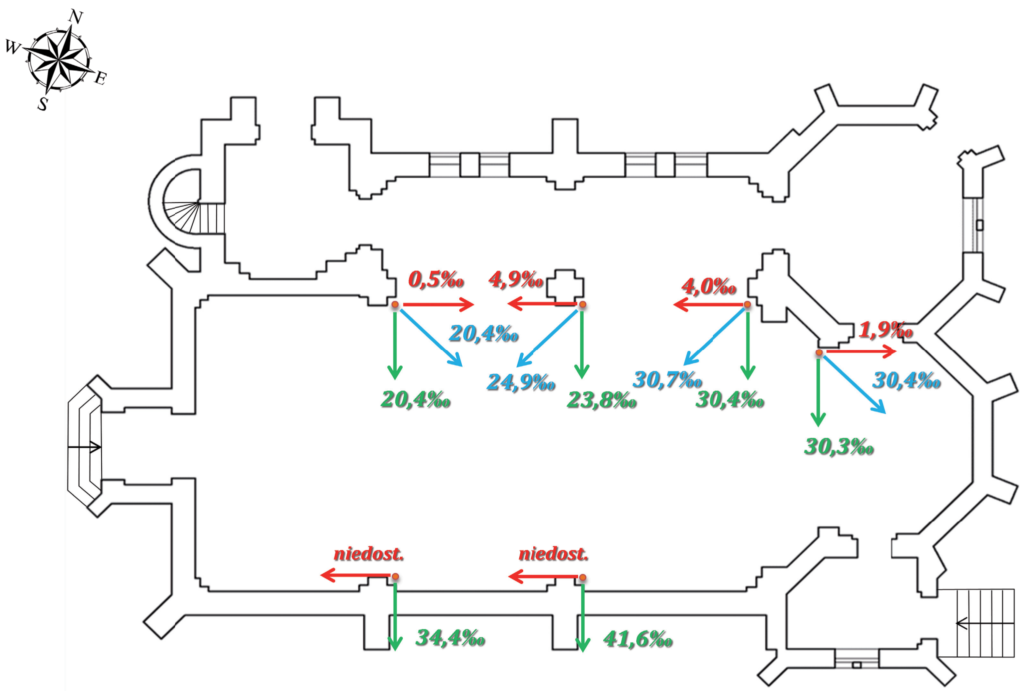


Fig. 6. The results of measurments of the church's building declination, performed by the main (*Tx av* = 2 mm/m, *Ty av* =30 mm/m)
Rys. 6. Wyniki pomiarów pochylenia obiektu kościoła wykonanych przez kopalnię (*Tx śr* = 2 mm/m, *Ty śr* =30 mm/m)

4. DECLINATION MEASURMENTS

Declination measurements can be performed in several ways:

1. Edge's vertical declination – spatial indentation of object's landmarks with tachymeter and calculating components along longitudinal and transverse axis of the object (fig. 6).
2. Measurements of the church's building before and after rectification with laser scanner and preparing 3D model (fig. 7–10).
3. Walls' vertical declination in dozens of points with electronic „promil" level and calculating com-

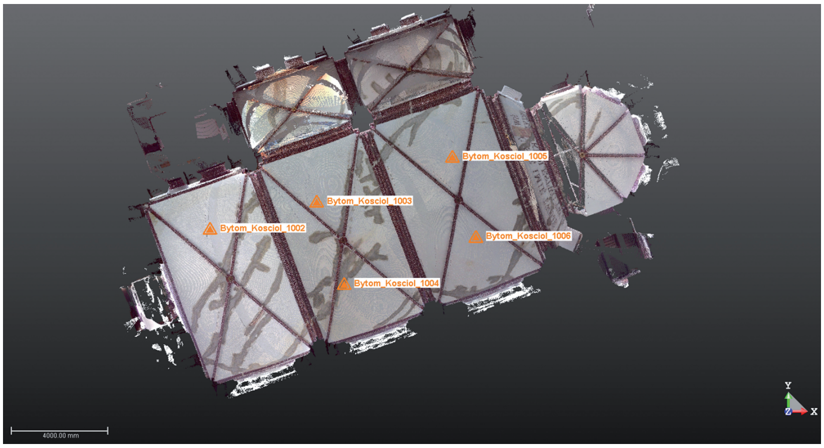


Fig. 7. Distribution of laser scanner 3D Trimble TX5 measuring positions. Visible signs of repair cracks in the ceiling
Rys. 7. Rozmieszczenie stanowisk pomiarowych skanera laserowego 3D Trimble TX5. Widoczne ślady naprawy pęknięć sklepienia

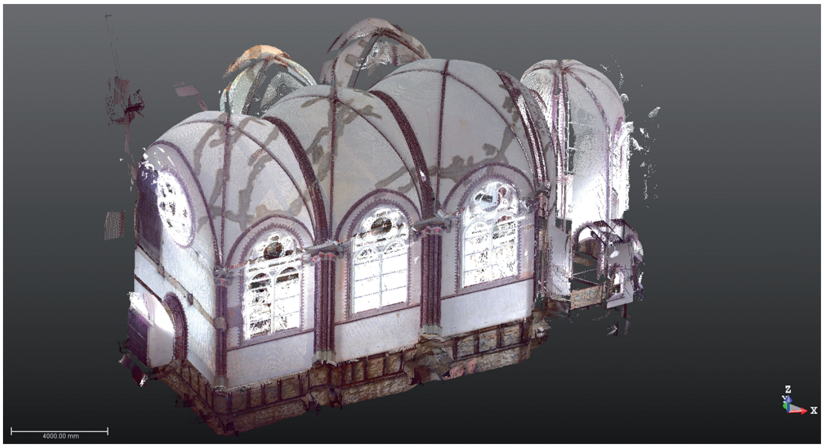


Fig. 8. Church's 3D model based on measurements performer in interiors
Rys. 8. Model 3D kościoła na bazie przeprowadzonych pomiarów wewnątrz obiektu

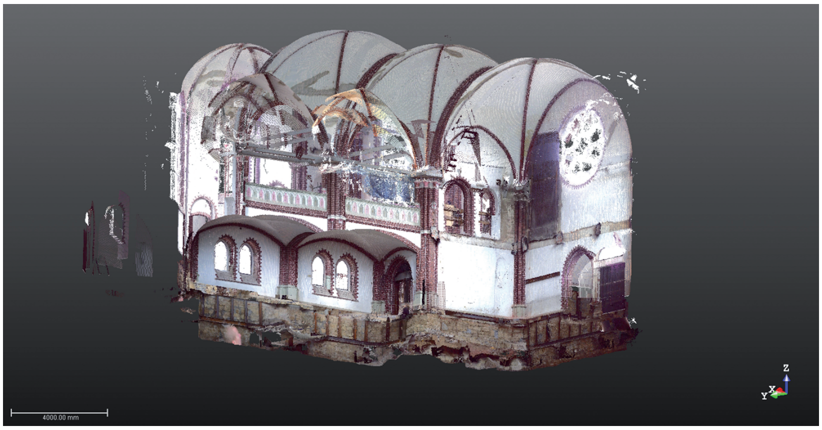
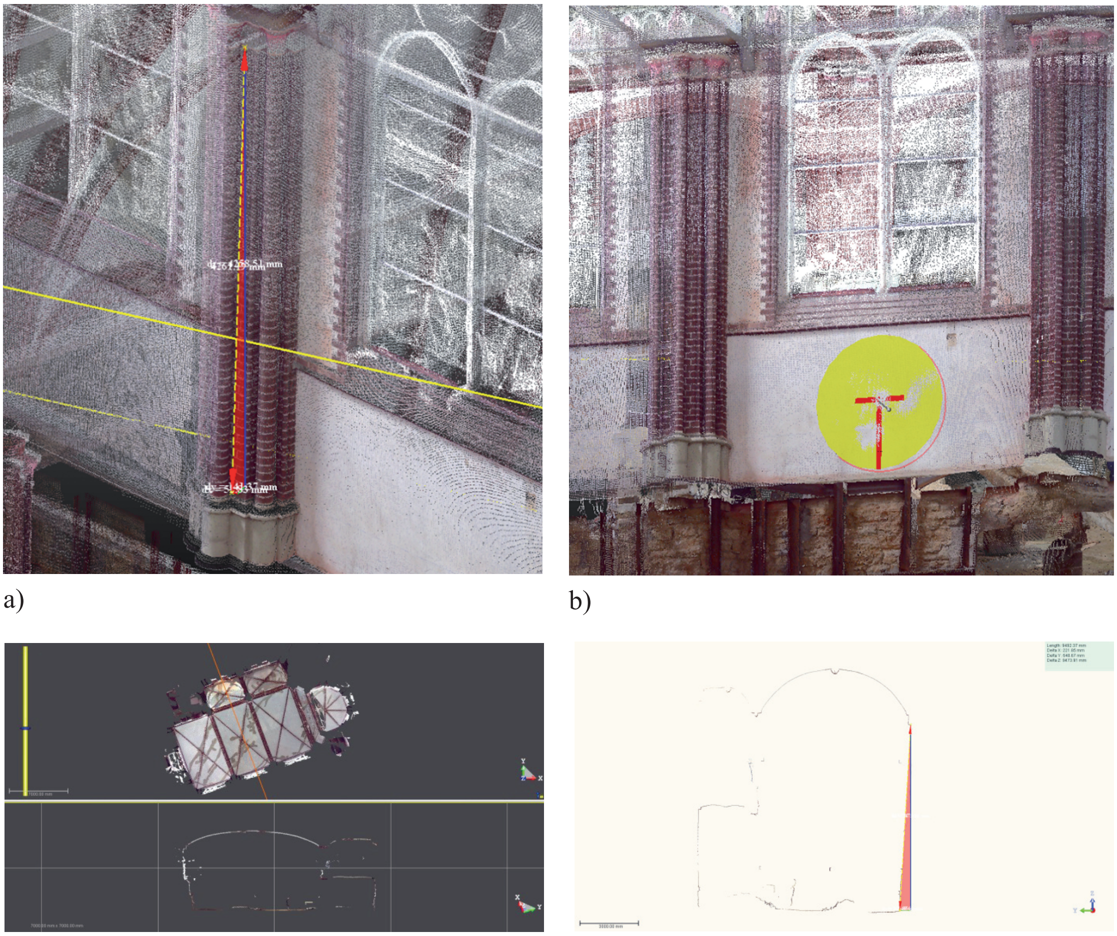


Fig. 9. Church's 3D model based on measurements performer in interiors
Rys. 9. Model 3D kościoła na bazie przeprowadzonych pomiarów wewnątrz obiektu



a) b) c) d)

Fig. 10. Example of declination measurement using 3D model: a) based on coordinates of the points at the top and bottom of the pillar $Ty = 35$ mm/m, b) based on plane orientation adjacent to a chosen object $Ty = 38$ mm/m, c) based on the measurement section of the church in the desired location $Ty = 39$ mm/m

Rys. 10. Przykład pomiaru pochylenia budowli z wykorzystaniem modelu 3D: a) w oparciu o współrzędne punktów u góry i u dołu filaru $Ty = 35$ mm/m, b) określenie orientacji płaszczyzny przyległej do wybranego fragmentu obiektu $Ty = 38$ mm/m, c) na podstawie pomiaru przekroju kościoła w wybranym miejscu $Ty = 39$ mm/m

ponents of average deviation of vertical along longitudinal and transverse axis of the object (fig. 11).

4. Ceiling's declination – see point 3 – however due to removal of the floor inside the church there are no measurements available.

4.1. Edge's vertical declination

It is difficult to choose a sufficient long edges in the building object, especially in the church, therefore the method gives a small number of observations.

4.2. Laser scanner and 3D object's model

For measuring the interior of the church laser scanner 3D Trimble TX5 has been used. Two measuring cycles have been performed with the usage of terrestrial scanning technology, first one before and second one after rectification (Gruchlik 2015).

The church's measurements were carried out at five positions (fig. 4), with the following parameters for each position:

- resolution 28,2 Mpts
- quality x4

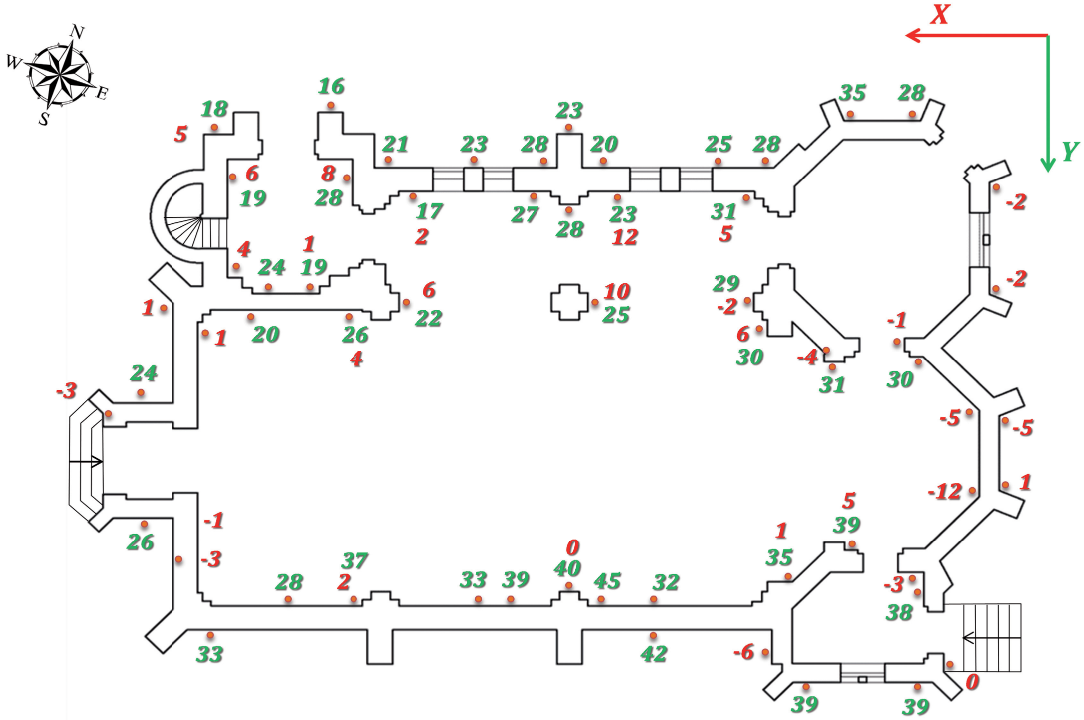


Fig. 11. Sketch to locate declination measurement points of the church building using the electronic level and the measured values of declination in two directions

Rys. 11. Szkic rozmieszczenia punktów pomiarowych pochylenia kościoła za pomocą poziomicy elektronicznej i pomiar wartości pochylenia w dwóch kierunkach

- AE metering mode – weighted horizontal
- Horizontal level 0–360°
- Vertical level -60–90°
- Scan size 8234x3414 pkt
- Enabled: compass, altimeter, inclinometer
- Duration: 5:35 min

The measurement results obtained in the form of point clouds have been registered by using Trimble® RealWorks software. Registration is the process of combining point clouds of the same object obtained from different measuring positions. Absolute orientation is given to all measuring positions and is calculated with least square method. For the church, absolute orientation was done by transforming all scans into one local system (of reference scan). Transformation was based on clearly identifiable common points of point clouds from individual measuring positions. Scan registration report results are given in Table 1.

3D model of the church have been developed on the basis of colour point clouds. This allowed detailed analysis of the object's spatial solid. Virtual, three-dimensional model of scanned object allows to develop suggestive visualization and presentations like "virtual tours". This allows to present object's technical condition, asses and register its damage. Data received from scanning can be further developed in the following areas (Florkowska, Kanciruk 2015):

- 2D drawings (projections, sections, profiles),
- Databases joining 3D graphics with descriptive elements,
- Comparing the changes in the object in time periods.

Declination measurements results in this area are in accordance with the results of measurements using the electronic level.

The measurement of the orientation of the plane adjacent to any selected portion of the object allows to evaluate changes in its declination before and after rectification. For wall visible at fig. 10b declination from 38 mm/m has decreased into 8 mm/m. Change of declination 30 mm/m is consistent with a given rectification angle.

Table 1. The report from the registration of the results of measurements of individual positions
Tablica 1. Raport z rejestracji wyników pomiarów z poszczególnych stanowisk

Registration Report

Date: Fri Nov 28 15:38:08 2014
Project Name: Kosciol_Matki_Ewy_XI-2014

Linear Measurement Units: Millimeters
Coordinates System: X, Y, Z

Overall cloud-to-cloud error: 0.90 mm

Bytom_Kosciol_1002 – 4 **Station(s) with Points in Common –**

Object Name	Cloud-to-cloud error	Coincident Points (%)
Bytom_Kosciol_1003	0.85 mm	79.0%
Bytom_Kosciol_1004	0.78 mm	77.7%
Bytom_Kosciol_1005	1.11 mm	67.7%
Bytom_Kosciol_1006	1.18 mm	66.1%

Bytom_Kosciol_1003 – 4 **Station(s) with Points in Common –**

Object Name	Cloud-to-cloud error	Coincident Points (%)
Bytom_Kosciol_1002	0.85 mm	79.0%
Bytom_Kosciol_1004	0.75 mm	83.2%
Bytom_Kosciol_1005	0.92 mm	70.4%
Bytom_Kosciol_1006	0.90 mm	69.2%

Bytom_Kosciol_1004 – 4 **Station(s) with Points in Common –**

Object Name	Cloud-to-cloud error	Coincident Points (%)
Bytom_Kosciol_1002	0.78 mm	77.7%
Bytom_Kosciol_1003	0.75 mm	83.2%
Bytom_Kosciol_1005	1.00 mm	70.2%
Bytom_Kosciol_1006	0.93 mm	72.6%

Bytom_Kosciol_1005 – 4 **Station(s) with Points in Common –**

Object Name	Cloud-to-cloud error	Coincident Points (%)
Bytom_Kosciol_1002	1.11 mm	67.7%
Bytom_Kosciol_1003	0.92 mm	70.4%
Bytom_Kosciol_1004	1.00 mm	70.2%
Bytom_Kosciol_1006	0.66 mm	81.3%

Bytom_Kosciol_1006 – 4 **Station(s) with Points in Common –**

Object Name	Cloud-to-cloud error	Coincident Points (%)
Bytom_Kosciol_1002	1.18 mm	66.1%
Bytom_Kosciol_1003	0.90 mm	69.2%
Bytom_Kosciol_1004	0.93 mm	72.6%
Bytom_Kosciol_1005	0.66 mm	81.3%

4.3. Measurement using electronic „promil" level

During tilt measurements 80cm long level from Nedo has been used, its readability is 0,3 mm/m. Declination measurements have been performed by applying the level to the wall at a height of around 1.2–1.8 m. Concave wall space were measured, that is, to the beginning and end of the level to adhere to it.

The fig. 11 shows measurement points inside and outside the building. Distribution of measured values is shown in fig. 12; the average value of declination along the transverse axis equals Ty=29 mm/m.

The evaluation of the normality of the declination measurements was performed using Kolomogorov-Smirnov and Lilliefors statistical tests, also graphs of normality were prepared. Value of the Kolomogorov-Smirnov statistic test and Lilliefors test is the same and amounts 0.11015, while the value of $p = 0.62019$ for the Kolomogorov-Smirnov test and $p = 0.19859$ for Lilliefors test. Both tests have shown that at the significance level $\alpha = 0.05$ null hypothesis that the analyzed data show the normal distribution can not be rejected.

5. SUMMARY

Rectified church building has been used in order to present different methods of measuring the declination of the object. All these methods complement each other and confirm high compatibility of the measurements results of buildings' declination.

3D laser scanner measurements are increasingly used in moving the actual shape of three-dimensional object into digital form. 3D models developed this way are the beginning of advanced numerical modelling of construction of the object.

Detecting changes over time by repeated measurement of the same surface is an interesting example of the use of laser scanning. This makes it possible to monitor the deformation processes in space and in time with millimetre accuracy.

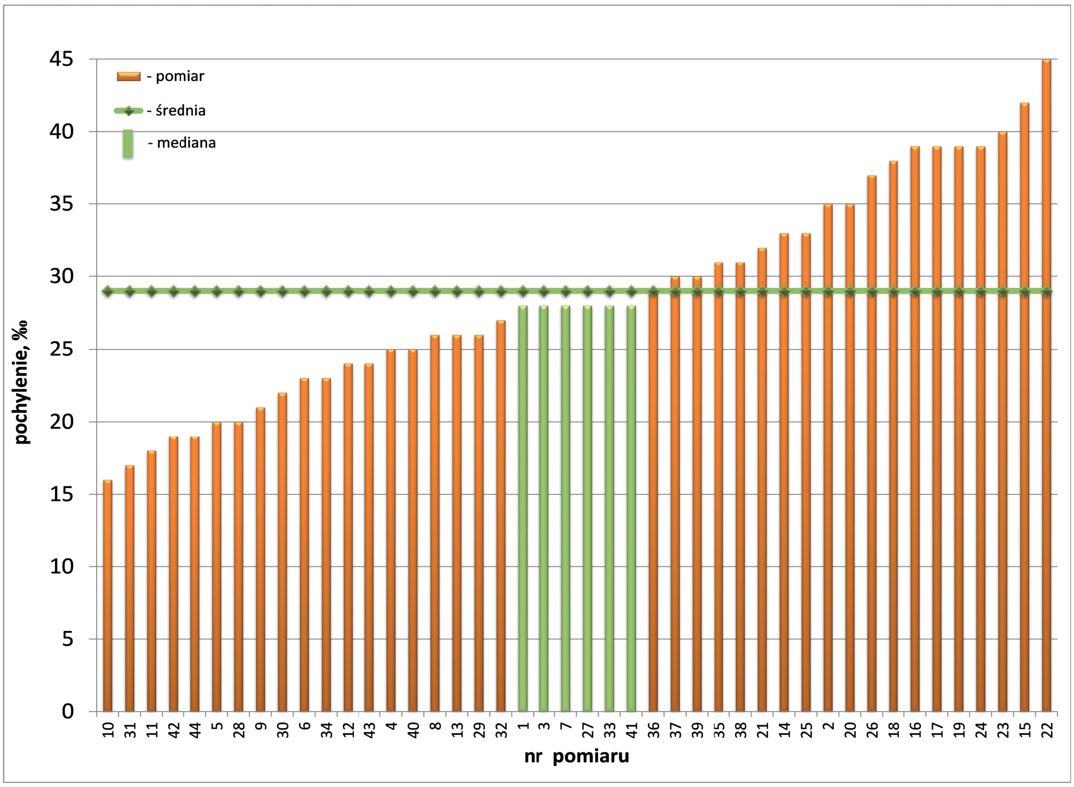


Fig. 12. Distribution of the declination of selected elements of church's building (according to fig. 11) and their average value (29 mm/m) and median (28 mm/m)

Rys. 12. Rozkład pochylenia wybranych elementów kościoła (wg rys. 11) oraz ich wartość średnia (29 mm/m) i mediana (28 mm/m)

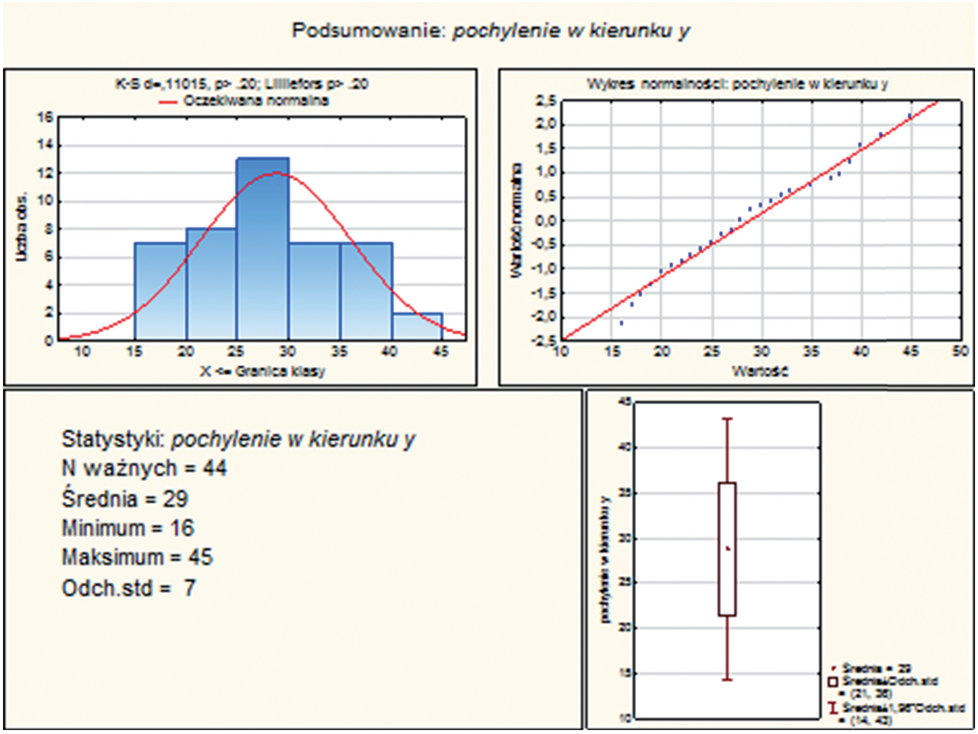


Fig. 13. Statistical analysis of the measurements
Rys. 13. Analiza statystyczna pomiarów

LITERATURA

Florkowska L., Kanciruk A.: *System zdalnego monitorowania deformacji obiektów budowlanych*. V Konferencja Naukowo-Szkoleniowa Bezpieczeństwo i Ochrona Obiektów Budowlanych, Rytro 17–19.10.2012 (w tekście 2015)

Gromysz K.: *Koncepcje wzmocnienia zabytkowego budynku neogotyckiego kościoła w związku z planowanym prostowaniem obiektu*. V Konferencja Naukowo-Szkoleniowa Bezpieczeństwo i Ochrona Obiektów Budowlanych, Karpacz 15–17.10.2014, „Przegląd Górniczy" 3/2015, s. 21–29

Gromysz K., Niemiec T.: *Wybrane problemy prostowania obiektów budowlanych wychylonych z pionu.* Prace Naukowe Głównego Instytutu Górnictwa „Górnictwo i Środowisko", Nr 4/1/2010, Katowice 2010. III Konferencja Naukowo-Szkoleniowa, Katowice-Ustroń 4–6.10.2010

Gruchlik P.: *Naziemne skanowanie laserowe 3D, doświadczenia i perspektywy,* „Przegląd Górniczy" 2015

Informacje nt. kościoła (Information about church): http://pl.wikipedia.org/wiki/Ko%C5%9Bci%C3%B3%C5%82_ewangelicko-augsburski_w_Bytomiu-Miechowicach

Kawulok M., *Ocena właściwości użytkowych budynków z uwagi na oddziaływania górnicze*. Prace naukowe Instytutu Techniki Budowlanej, Warszawa 2000

Kwiatek J. i inni: *Ochrona obiektów budowlanych na terenach górniczych*. Wydawnictwo Głównego Instytutu Górnictwa, Katowice 1997