VERSITA

Arch. Min. Sci., Vol. 57 (2012), No 3, p. 645–655

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI 10.2478/v10267-012-0041-2

LUCYNA FLORKOWSKA*

# BUILDING PROTECTION AGAINST THE BACKDROP OF CURRENT SITUATION AND GROWTH PERSPECTIVES FOR POLISH MINING INDUSTRY

# PROBLEMATYKA OCHRONY OBIEKTÓW BUDOWLANYCH NA TLE SYTUACJI I PERSPEKTYW ROZWOJU GÓRNICTWA W POLSCE

This paper discusses issues involved in protecting buildings and utilities infrastructure located on areas affected by mining exploration. They have been presented against the backdrop of current situation and growth perspectives for Polish mining.

Characteristics of Polish mineral deposits have been determined and the scale of mining-induced impact has been given as an aggregate mining areas and regions. Current situation and growth perspectives have been evaluated through analysing geological concessions granted by Ministry of the Environment.

The nature of mining influences induced by underground coal – black coal being the most intensively explored mineral in the country – mining has been discussed. Building protection issues have also been presented from three angles: forecasting of mining influences, designing protections and structural health monitoring.

**Keywords:** mining damage, protection of buildings, mining, development of mining industry

Ochrona powierzchni i obiektów budowlanych przed niekorzystnym wpływem eksploatacji górniczej stanowi w naszym kraju istotny problem naukowy i inżynierski. Sytuacja ta związana jest z licznymi zasobami złóż kopalin użytecznych oraz z istniejącą strukturą pozyskiwania energii, której źródłem w ponad 80% jest węgiel (*Gospodarka paliwowo-energetyczna*..., 2009; *Energetyka*…, 2010) (rys. 1).

Artykuł odnosi się do zagadnień związanych z ochroną zabudowy i infrastruktury technicznej na terenach objętych wpływami eksploatacji górniczej. Problematyka ta przedstawiona została na tle sytuacji i perspektyw rozwoju górnictwa w Polsce.

W pracy wymieniono najważniejsze złoża kopalin występujących na terenie kraju oraz podano zasięg oddziaływania prowadzonego wydobycia. Zestawienie polskich zasobów bilansowych wybranych kopalin opracowane na podstawie danych zawartych w dokumencie *Bilans Zasobów Kopalin i Wód Podziemnych w Polsce wg stanu na 31 XII 2010 r.* podano w tabeli 1.

Zasięg oddziaływania eksploatacji górniczej charakteryzuje sumaryczna powierzchnia zajmowana przez obszary górnicze w Polsce. Stanowi ona ponad 2,6% powierzchni całego kraju. Powierzchnia

* STRATA MECHANICS RESEARCH INSTITUTE OF THE POLISH ACADEMY OF SCIENCES, UL. REYMONTA 27, 30-059 KRAKÓW, POLAND

terenów górniczych wynosi natomiast ok. 5,3% (*Sektorowy program*..., 2005). Jest to ponad 17 200 km$^2$ powierzchni objętej potencjalnymi szkodami górniczymi. Największa koncentracja wydobycia ma miejsce na terenie Górnośląskiego Zagłębia Węglowego, gdzie występuje ok. 79% udokumentowanych zasobów bilansowych polskich węgli kamiennych – pozostających najintensywniej eksploatowaną w Polsce kopaliną.

Sytuacja bieżąca oraz perspektywy rozwoju górnictwa w Polsce ocenione zostały na podstawie analizy koncesji geologicznych wydawanych przez Ministerstwo Środowiska. Zestawienia koncesji na wydobywanie złóż węgla kamiennego oraz koncesji na poszukiwanie i rozpoznawanie złóż gazu łupkowego w Polsce, wg stanu na dzień 1 czerwca 2012 r., podano w tabelach 2 i 3.

Prowadzenie eksploatacji górniczej w tak dużej skali powoduje liczne problemy wynikające z jej oddziaływania na środowisko. W przypadku górnictwa podziemnego oddziaływanie to wynika przede wszystkim z naruszenia naturalnej struktury górotworu, co pociąga za sobą szereg następstw klasyfikowanych jako bezpośrednie i pośrednie skutki eksploatacji górniczej (Kwiatek, 1997; Florkowska, 2010a). Najbardziej odczuwalne pozostają niewątpliwie zmiany morfologii terenu i przekształcenia hydrogeologiczne, które powodują szkody w infrastrukturze technicznej oraz zabudowie a także wstrząsy (Firek & Wodyński, 2012; Walaszczyk i in., 2009).

Podstawą ochrony zabudowy jest znajomość rodzaju i wielkości oddziaływań wywołanych planowaną eksploatacją. Ważne jest zatem, by umiejętnie prognozować skutki projektowanych robót górniczych, szczególnie w zakresie deformacji przypowierzchniowych warstw górotworu. Prawidłowe zabezpieczenie budynku zagrożonego wystąpieniem szkód górniczych wymaga spełnienia dodatkowych rygorów konstrukcyjnych, wynikających z konieczności zabezpieczenia konstrukcji przed niekorzystnymi deformacjami podłoża (Kawulok, 2005). Deformacje te mają swe źródło zarówno w bezpośrednim oddziaływaniu prowadzonych robót wydobywczych, jak i w zmianach właściwości podłoża następujących wskutek wielokrotnie powtarzających się procesów kształtowania się niecki górniczej. Prawidłowe wyznaczenie wielkości oraz rozkładów czasowo-przestrzennych tych oddziaływań ma podstawowe znaczenie dla profilaktyki szkód górniczych, bowiem stanowi zarówno podstawę projektowania zabezpieczeń jak i sprawdzania nośności konstrukcji istniejących. W przypadku obiektów o szczególnym znaczeniu, których koszty realizacji są pokaźne, zaś ewentualna awaria przynieść może ogromne straty, wskazane jest dokonanie indywidualnej, szczegółowej analizy, uwzględniającej specyficzne warunki geotechniczne, górnicze i konstrukcyjne inwestycji. Dobrym narzędziem tego rodzaju analiz jest modelowanie numeryczne.

Istotnym elementem profilaktyki jest również stały nadzór i obserwacja stanu obiektu w trakcie ujawniania się głównych wpływów eksploatacji. Monitoring automatyczny jest w tym przypadku użytecznym narzędziem wspomagania nadzoru technicznego. W Instytucie Mechaniki Górotworu PAN opracowywana jest metodyka, która, poprzez połączenie symulacji numerycznej z systemem pomiarowym, umożliwia bieżące i zdalne śledzenie zmian stanu konstrukcji w trakcie oddziaływania górniczych deformacji podłoża (Florkowska, 2010; Kanciruk, 2005).

Problem ochrony obiektu budowlanego przed oddziaływaniami wywoływanymi eksploatacją górniczą należy niewątpliwie do klasy trudnych zagadnień geotechnicznych. Wymaga zarówno opracowania trafnej prognozy tych oddziaływań, jak i prawidłowego wyznaczenia wywołanych nimi naprężeń w konstrukcji obiektu oraz zaprojektowania i wykonania skutecznych zabezpieczeń. Warto zauważyć, że problem ten pozostaje aktualny także w przypadku ograniczenia bądź zaprzestania działalności wydobywczej. Zagospodarowanie tzw. terenów pogórniczych już dzisiaj wymaga podejmowania odpowiednich działań i stosowania rozwiązań chroniących powstające obiekty przed procesami deformacyjnymi, które zachodzić będą w silnie naruszonym górotworze jeszcze w długim okresie czasu.

Koszty szkód powodowanych przez górnictwo w obiektach budowlanych są w skali kraju niebagatelne. W roku 2010 wyniosły one ponad 350 mln złotych (Raport GUS „Ochrona środowiska 2011"). Niestety, niemal całość nakładów skierowana była na naprawę powstałych uszkodzeń. Zabezpieczenia i profilaktyka to, według wspomnianego raportu, niecałe 8% wymienionej kwoty. Z całą pewnością nie są to dobre proporcje. Wydaje się, że należałoby skierować więcej wysiłków w stronę poprawy procedur profilaktyki oraz prowadzenia badań naukowych mających na celu opracowywanie odpowiednich narzędzi prognozowania i monitorowania oddziaływań górniczych w obiektach budowlanych.

**Słowa kluczowe:** szkody górnicze, ochrona obiektów budowlanych, górnictwo, rozwój górnictwa

## Introduction

Protecting surfaces and buildings against mining-induced damages have continually posed a significant challenge for both engineers and scientists dealing with issues related to mining exploration. At the heart of this situation lay numerous mineral deposits and current energy mix, where coal accounts for over 80% of produced energy (*Energy statistics*..., 2009; *Energy*..., 2010) (Fig. 1).

The extractive industry is a substantial part of Polish economy. Domestically extracted energy resources are sufficient to cover the majority of domestic electricity demand. Furthermore, the recently discovered shale gas deposits augur well for energy independence of Poland (Nagy & Siemek, 2011). In face of those facts, the good perspectives for the mining industry are a foregone conclusion. Hence, the plethora of issues concerning mining-induced damage to natural environment and infrastructure remains a viable and important topic, which calls for ever-effective solutions.

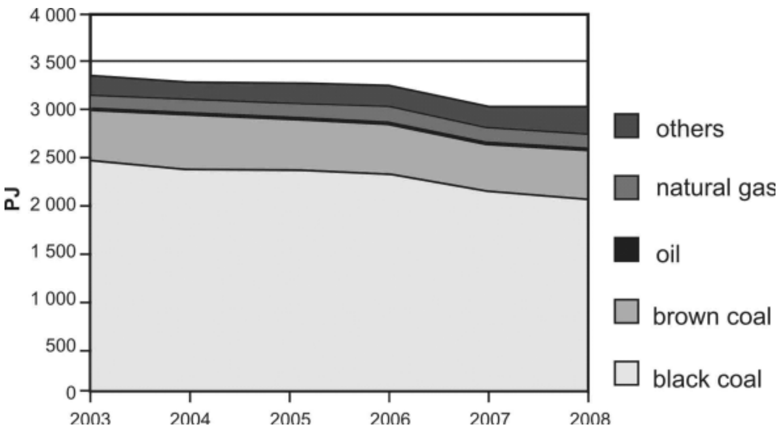


Fig. 1. Primary Energy supply in Poland
(source: Central Statistical Office: Energy statistics 2007, 2008. Warsaw, 2009)

## 1. Mineral deposits

Numerous deposits of usable minerals scattered throughout Poland mean mining exploration impacts substantial area of the country. According to data obtained by Polish Geological Institute and included in *The balance of mineral resources deposits in Poland as of 31.12.2011*, there are the following deposits across Poland:

- 641 – energy resources deposits,
- 35 – metal resources deposits,
- 49 – chemical resources deposits,
- 11 075 – rock raw resources deposits,
- 86 – medicinal water, thermal water and saline deposits.

Among energy resources are 332 gas field deposits (natural gas and coal bed methane), 82 oil reservoirs and 229 coal deposits (both black and brown coal). Table 1 shows balance of key energy, metal and chemical resources in Poland in 2010.

TABLE 1

Balance of selected energy, metal and chemical resources deposits in Poland (based on: *The balance of mineral resources deposits in Poland as of 31.12.2011* Polish Geological Institutes, 2011)

| Mineral | Number of deposits | | Remaining resources [m tonnes] or [m m$^3$] of gases | |
|---|---|---|---|---|
| | total | including explored | total (31.12.2010) | including explored |
| **Energy resources** | | | | |
| natural gas | 280 | 190 | 145.15 | 120.89 |
| coal bed methane | 52 | 23 | 90.00 | 25.73 |
| petroleum | 82 | 66 | 25.24 | 24.66 |
| brown coal | 86 | 11 | 19 818.88 | 1 686.54 |
| black coal | 143 | 48 | 45 143.86 | 16 851.68 |
| **Metal resources** | | | | |
| zinc and lead ores | 20 | 3 | 79.87 | 20.28 |
| copper ore | 14 | 6 | 1 752.88 | 1 437.30 |
| **Chemical raw materials** | | | | |
| sulphur | 18 | 5 | 513.89 | 28.01 |
| mineral salt | 19 | 4 | 85 334.51 | 12 506.14 |

## 2. Mining areas and regions

Mining regions cover a total of 2.6% of Poland, whilst mining areas – approx. 5.3% (including 3.1% in open-pit mines, 0.8% in underground mines, 1.4% in borehole mines) (*Sectoral program*..., 2005). It amounts to over 17 200 km$^2$ potentially affected by mining damage.

Across the main mining area in Poland – Upper Silesian Coal Basin – there are approx. 79% documented black coal deposits from the balance of mineral resources. Nearly all operational collieries are located there (apart from Bogdanka colliery located in Lublin Coal Basin). The USCB covers an area (within Polish borders) of 5 600 km$^2$ of which 20% is being currently explored, 11% are identified reserves, 9% are worked out deposits and 15% abandoned deposits. Approx. 23% of the area are useful mineral resources where deposits are located 1250-1300 m deep (according to Polish Geological Institute data – *Mineral Resources of Poland*).

The largest mining company in Europe – Kompania Weglowa SA – operates in the USCB. The mining region of 16 mines part of KW SA covers an area of approx. 719 km$^2$ and spans across 48 municipalities and two voivodeships: Silesian and Malopolska. Second by size Polish mining company is Katowice Capital Group including Katowice Coal Holding (5 mines) and daughter mine “Kazimierz Juliusz”. Mining regions of KCG cover 227 km$^2$ and span across nine cities. Over 460 km$^2$ is covered by mining regions used by KGHM Polska Miedz SA to explore the Europe’s largest copper ores located between Lubin, Sieraszowice and Glogow.

## 3. Growth perspectives for the mining industry

The most intensively explored mineral in Poland is black coal. In 2011 76.7 million tonnes was excavated of it (Coal information, 2011, Central Statistical Office Statistical Yearbook, 2011). Annual brown coal mining (2010) is 56.52 million tonnes and copper ore – 22.45 million tonnes.

As for 1st June 2012 (according to Ministry of the Environment), granted in Poland have been 58 black coal concessions, 14 brown coal concessions, 8 copper concessions and 235 concessions for hydrocarbons exploitation (petroleum and natural gas). As near as half of coal concessions have been granted to Kompania Weglowa SA, which remains the country's largest company in the extractive industry (tab. 2).

Indicative of how promising are the growth perspectives is the number of granted concession for prospecting and/or exploration of mineral deposits. A total of 20 black coal concessions have been granted, 7 brown coal concessions, 20 copper ore concessions and 255 hydrocarbons concessions (petroleum and natural gas). There are also 3 exploitation and 13 prospecting / exploration concessions for coalbed methane. According to the Ministry of the Environment, a total of 110 concessions have been granted for prospecting and/or exploration of oil and natural gas deposits – both conventional and unconventional (shale gas). The number of applications submitted by carbohydrates exploration companies demonstrates their interest. Table 3 lists companies holding concession for prospecting and/or exploration of shale gas fields, as for 1st June 2012 (according to the Ministry of the Environment).

Figure 2 shows concession areas and regions where concession applications have been submitted for exploration of shale gas. As the illustration shows, they cover substantial areas of the country, however, in comparison to areas the coal deposits, are lightly populated areas.

The type of environmental impact and nuisance caused by potential shale gas exploration are different from underground mining of fossil minerals. Nuisance in this case is noise-related and includes tremors generated during drilling and fracking. Among threats posed by shale gas exploration is contamination of environment with fracking fluids and contamination of groundwater with methane and drilling fluids (Nagy & Siemek, 2012).

TABLE 2

Concession areas in Poland with black coal deposits as for 1st June 2012
(source: Ministry of the Environment)

| Black coal concessions (total of 58 concessions) as for 1st June 2012 | |
|---|---|
| **Concession holder** | **Number of concession** |
| Kompania Weglowa SA | 27 |
| Katowice Capital Group | 11 |
| Jastrzebska Spolka Weglowa SA | 8 |
| Południowy Koncern Węglowy SA | 7 |
| Eko-Plus Ltd. | 1 |
| NWR Karbonia SA | 1 |
| Lubelski Węgiel „Bogdanka" SA | 1 |
| Przedsiębiorstwo Górnicze „Silesia" Sp. z o.o. | 1 |
| ZG Siltech Ltd. | 1 |

TABLE 3

Concession areas in Poland with shale gas field as for 1st June 2012
(source: Ministry of the Environment)

| **Concession for prospecting and/or exploration of shale gas fields (total of 110 concessions) as for 1st June 2012** | |
|---|---|
| **Concession holder** | **Number of concession** |
| PGNiG SA | 15 |
| Marathon Oil Poland Ltd. | 11 |
| Lotos Petrobaltic SA | 7 |
| Orlen Upstream Ltd. | 7 |
| Lane Energy Poland Ltd. | 6 |
| Strzelecki Energia Ltd. | 6 |
| Exxon Mobil Exploration and Production Poland Ltd. | 6 |
| DPV Service Ltd. | 5 |
| Silurian Ltd. | 5 |
| Chevron Poland Energy Resources Ltd. | 4 |
| Wisent Oil & Gas Ltd. | 4 |
| Eco Energy 2010 Ltd. | 4 |
| Lane Resources Poland Ltd. | 3 |
| Eni Polska Ltd. | 3 |
| Talisman Energy Ltd. | 3 |
| Saponis Investments Ltd. | 3 |
| Indiana Investments Ltd. | 3 |
| Lisea Energy Ltd. | 3 |
| Cuadrilla Polska Ltd. | 2 |
| Gora Energy Resources Ltd. | 2 |
| Aurelian Oil & Gas Poland Ltd. | 2 |
| Vabush Energy Ltd. | 1 |
| Joyce Investments Ltd. | 1 |
| Maryani Investments Ltd. | 1 |
| Helland Investments Ltd. | 1 |
| Composite Energy Poland Ltd. | 1 |
| Mac Oil Poland Ltd. | 1 |

## 4. Mining damage

Exploration of carbohydrates is inextricably linked with changes it causes to the environment. In case of underground mining, its impact manifests itself with disturbing structure of the natural rock mass, which snowballs into a range of consequences classified both as direct and indirect effects of mining exploration (Kwiatek, 1997; Florkowska, 2010A). The most tangible, however, are changes in land relief and hydro-geological transformations which cause damage to utilities infrastructure and buildings, as well as tremors (Firek & Wodynski, 2012; Walaszczyk et al., 2009).

Moreover, located on areas where exploration takes place are processing and production facilities, and housing estates creating urban agglomerations. Those areas are densely built-up with industrial and residential buildings endangered by mining influences.

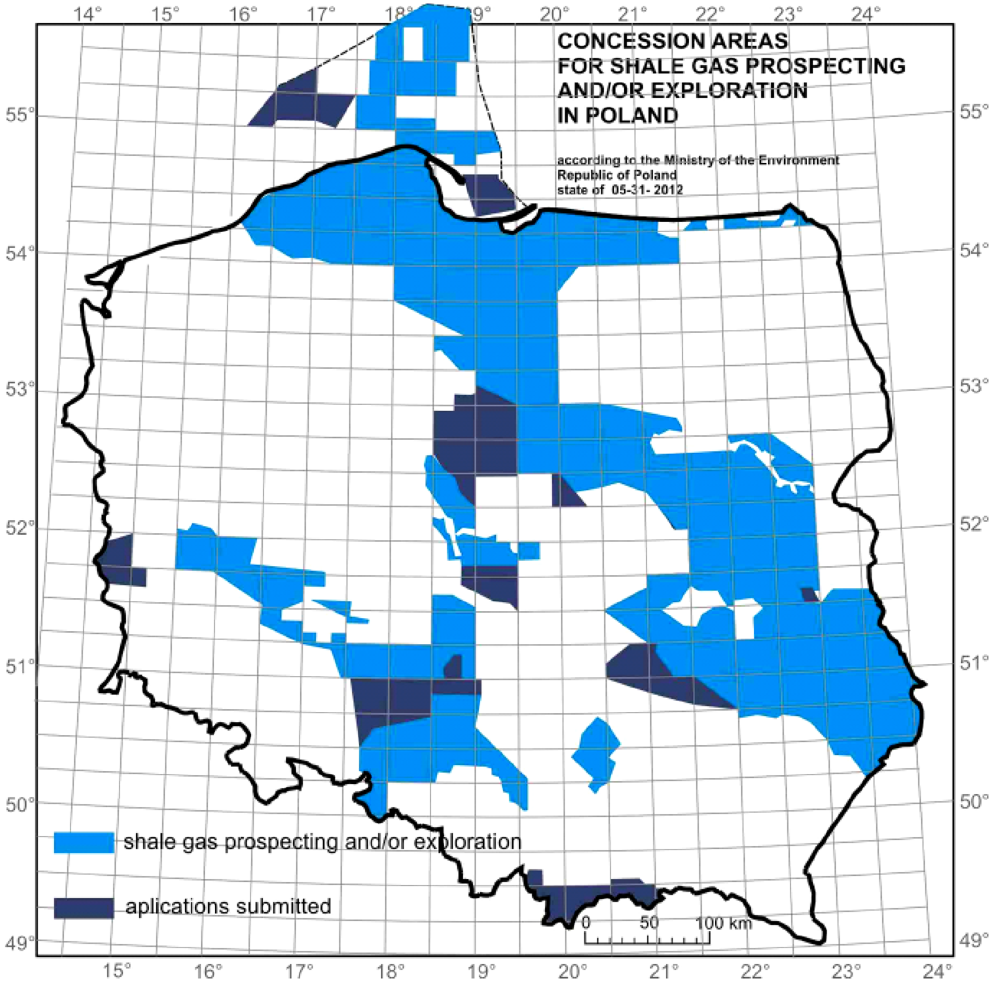


Fig. 2 Concessions areas for shale gas exploration (according to the Ministry of the Environment)

Key reason for damaged buildings and infrastructure are mining-induced land deformations related to mining basin forming on the surface and the tremors. Repair costs are covered by the mining company.

According to report by the Central Statistical Office "Environment 2011", financial resources committed to repairing mining damage in 2010 totalled over 350 million PLN. Interestingly, the above-mentioned report states that outlays incurred for building and equipment protections amounted to 8% of that sum. The other costs included repairs and compensations. The most numerous group of structures with sustained damage were residential buildings (3 365). Requiring repair did among other 158 public utility facilities, 32 industrial facilities and 146 road structures, bridges and overpasses.

The above data indicates that issues related to building protection against impact of mining exploration remains a current matter. Moreover, it seems that preventative measures should shift from claims management to protection and structural health monitoring.

## 5. Surface and structural health protection

Key for surface and structural health protection is knowledge on characteristics and magnitude of influences induced by planned exploration. Hence it is important to competently forecast effects of planned mining work, especially as far as deformation of rock mass surface layers is concerned. An undeniable achievement in that respect is the commonly used in continuous deformation forecasting Budryk-Knothy theory (Knothe, 1952, 1953a and b, 1984). Due to substantial disturbance to the rock mass, however, in areas where for almost two centuries often an excess of a dozen seams have been excavated (as in Upper Silesia) correct forecasting of future, planned explorations has to be carried out on an individual basis (Florkowska, 2010a). Developing an accurate forecast of mining influences is key from the standpoint of mining damage prevention.

Correct protection of building endangered by mining damage requires adhering to additional building rigours dictated by the need to protect structures against surface deformation (Kawulok, 2005). Those deformations are caused both directly by mining work and changes in subsoil properties due to repeated deformation influences. In light of the above-mentioned, mining influences of planned exploration on buildings is a complex issue. At the same time, determining the magnitude and time-space distribution of those influences is fundamental for effective mining prevention, because it gives grounds for both designing protection systems as well as verifying structural capacity of existing buildings. Both the issues of determining deformation influences and designing load-bearing structures resilient to those influences requires specialist knowledge and skills.

Legal provisions require the designer to introduce adequate protection systems provided the building is located within areas affected by mining exploration influences. Regulation by the Minister of Infrastructure from 12th April 2002 *concerning technical requirements for buildings and their location* (Journal of Laws from, No. 75, item 690 as amended) states that "*Within areas influenced by mining exploration, structural building protection shall be used adequately to the threat posed by forecasted mining influences, defined as mining-induced strains, deformations and tremors*" (§ 205). There is not, however, a single standard concerning design of buildings on mining areas. Methods of factoring in mining influences in building designs and designing methods of typical buildings are given by guidelines issued by the Building Research Institute (BRS manual..., 1993, 1994, 2003, 2004, 2007). Due to no standardisation in that area, they are usually used for calculation assumptions in projects implemented within mining areas.

In case of important structures, where investment outlays are substantial and any potential failure could cause tremendous losses, it is recommended to carry out a detailed analysis on an individual basis which would factor in particular geotechnical conditions, mining conditions and structure of the building. Developed at The Strata Mechanics Research Institute was a methodology for project-based analysis of underground mining influences exerted on buildings (Florkowska, 2010). The concept behind it is based on using numerical modelling in conjunction with laboratory experiments and *in situ* measurements. An advanced building – deforming subsoil numerical model is under development using non-linear mechanics methods. Data for determining boundary and initial conditions, and mathematical model parameters are determined based on results obtained from purpose-designed research program. This methodology enables to numerically simulate the entire process of mining-induced surface deformation influencing given structure. Computations return time-space distributions of stress, strain and displacements caused by mining influences which give in turn sound grounds to design building protection systems.

## 6. Structural health monitoring of endangered buildings

Safety assurance for structures exposed to surface deformation involves above all designing and building adequate protection systems, but also structural health monitoring on an on-going basis as the deformation processes take place in the subsoil (Ajdukiewicz, 2012; Kowalewski 2010; Witakowski, 2010). The most popular, and thus far the most reliable monitoring method is constant technical supervision which involves monitoring structural health of buildings on a regular basis by experts with required expertise and experience. Should any particular need arise, additionally taken with adequate frequency are geodetic measurements of building deformation using datum points. A measure becoming ever-widely used apart from technical supervision are automatic deformations monitoring systems. This technology uses either different measuring systems including "traditional" and satellite geodetic measurements, and strain gauges or video systems (Witakowski, 2010).

Currently under development at The Strata Mechanics Research Institute is a method, which through combining numerical simulation with measuring system would enable on-going and remote surveillance over structural condition during mining-induced surface deformation. The idea behind the system is to correlate virtual sensors composed into numerical model of the building with sensors part of the measuring system operating at the site. Components of this system include vibrating wire strain gauges connected to developed by SMRI device called Telemetric Wire Gauge (TMS1) (Kanciruk, 2005). Using the TMS1 enables data transmission via mobile network to any given e-mail mailbox. Therefore, this solution allows constant monitoring of mining-induced strain fluctuations (Florkowska, 2010b).

Despite unquestionable benefits of the automatic deformation monitoring systems, they are not capable to operate as autonomous structural health monitoring system. It seems as if they are a key element in safety assurance, but they have to become more commonly used as part of preventative measures, using expert knowledge and experience of individuals responsible for technical supervision over the building.

## 7. Summary

The issues of building protection within areas affected by mining exploration remain an important problem for many regions across Poland. This particularly applies to Upper Silesian Basin, where the magnitude of mining damage becomes ever-increasing. Protecting both the existing as well as historical buildings in tandem with developing effective design and monitoring methods for safety purposes is key for safety assurance.

Current situation and growth perspectives for the mining industry lead to conclusion that it should grow in the foreseeable short-term future. The extractive industry is a critical part of Polish economy, and coal is used to produce 86% of domestically-produced energy (Central Statistical

Office 2009: *Energy*... 2010) (Fig. 2). Hence, the mining industry is crucial for Polish energy security (Dubinski & Tajdus, 2007). Currently conducted are seismic surveying and identification works for energy resources. New geological concessions are granted and new mines are planned. Thus, one should reckon with the fact the surface area of mining region will expand on a continuous basis. In those circumstances, efforts aimed at finding solutions reducing negative mining influences on buildings are a problem important for both premises owners and mining companies which cover potential losses caused by their operations.

Building protection against mining-induced influences is beyond doubt a demanding geotechnical issue. It requires not only accurate and reliable forecasting, but also to correctly determine mining-induced stresses in building's load-bearing structure as well as designing and building sound protection systems. Thanks to current state of arts in modern computational techniques, measuring technologies, building and geotechnic technologies this is – despite the complexity – a feasible task.

Note that discussed in this paper issues remain important even should the extractive operations be limited or stopped altogether. Developing post-mining areas already requires preventative measures and actions to be deployed to protect planned buildings against deformation processes which are to take place in highly disturbed rock mass over the long-term.

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*Received: 16 January 2012*