Studia Geotechnica et Mechanica, Vol. XXXIII, No. 1, 2011

THE RELATIONS BETWEEN GSI-2004 AND MICROSCOPIC EMS-98 SCALES IN ASSESSING THE RESULTS OF MINING SHOCKS IN OZ/ZG RUDNA

JACEK BOROŃ, MACIEJ MINCH, ALEKSANDER TROCHANOWSKI

Building Engineering Department, Wrocław University of Technology,
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland. E-mail: jacek.boron@pwr.wroc.pl

Abstract: The empirical GSI-2004 scale used in LGOM (Legnica-Głogów Copper District) in order to assess the intensity of mining shocks was compared with the macroseismic MSK-64 and EMS-98 macroscales. The MSK-64 scale was considered to be an element of conversion into the current EMS-98 scale. The final result of the comparison was the identification of the levels of seismic intensity in the range available for the GSI-2004 and EMS-98 scales. The directions of possible modernization of the GSI-2004 scale with using all the advantages of the macroseismic EMS-98 scale have been defined.

1. INTRODUCTION

Macroseismic scales allowing the assessment of seismic occurrences (earthquakes) have significantly been modified since they were formulated. Such scales measure the intensity of earthquakes (of the impact force) based on their results shown on the earth's surface. At the beginning of the twentieth century many of such scales were created; they had a distinct regional character and referred mainly to the influence of earthquakes on buildings. The occurrences of mining shocks are in some specified statistics and parameters similar to the occurrences of earthquakes. Therefore, in order to define the influence of mining shocks on buildings, the scales, similar in some aspects to macroseismic scales, have also been created. Because of a lack of scales of mining shocks in the LGOM, macroseismic scales, for some period of time, were adjusted to local conditions of the paraseismic influences (mining seismic). In order to assess the results of mining shocks, use of macroseismic scales was made in individual expertises provided by scientific and research centers with an appropriate analysis of paraseismic occurrences. There was no possibility of applying macroseismic scales to the assessment of the effect of all mining shocks on the earth's surface. A long period of observing such an effect and also the measurements of ground vibrations in the area, where an increase of vibration frequency and prolonged time of those vibrations occur, allowed the Central Mining Institute in Katowice to formulate in 2004 the Mining Scale of Intensity (GSI-2004) for LGOM conditions. This scale was introduced to common usage in LGOM in 2006, just after accepting it by the Commission of Surface Protection of the State Mining Authority (WUG) in Katowice.

The aim of this paper was to define the relations between the GSI-2004 scale and the more recent seismic scale EMS-98 (European Macroseismic Scale) published by ESC (European Seismological Commission; Working Group "Macroseismic Scales") in Luxemburg in 1998. In order to establish these relationships, a full analysis of the GSI-2004 and EMS-98 scales with all possible parameters of the harmfulness of ground vibrations and the assessment of the hypothetic and real damage to buildings is necessary. The damage resulting from seismic activity differs fundamentally from the damage due to paraseismic activity connected with mining shocks. It is possible to find some common elements in those scales, e.g. for the strongest mining shocks, which took place in O/ZG Rudna, when the damage to buildings was similar to that of weak earthquakes. An analytic formulation of possible relationships in these scales is indispensable for the development of the GSI-2004 scale by adding to it the quantification of the probability of the occurrence of the types of buildings and also by specifying the character and type of this damage.

2. MACROSEISMIC SCALES

Scales adopted as the consequence of the classification of earthquake results were used to assess the harmfulness of vibrations transmitted from the ground to buildings. The results of earthquake with an appropriate level of intensity for each scale are descriptive in a macroscale, observed without a dynamic analysis of the occurrence and based on appropriate measurements. Because of this, the parameters of vibrations (a speed acceleration) are approximate, and scales are called *macroseismic scales*. It should be stressed that despite their imperfection they are useful and in the case of a lack of appropriate measuring data, necessary to define the results of an earthquake on the surface.

These scales have been permanently modified based on the current knowledge and experience in this field at that time. Among them it is necessary to mention the most important historical scales such as:

- the six-stage *Mercalli scale*,
- the twelve-stage modified *Mercalli (MM) scale*,
- the twelve-stage *Mercalli–Cancani (MC) scale*,
- the twelve-stage *Mercalli–Cancani–Sieberg (MCS) scale*,
- the twelve-stage *Miedwiediew–Sponheuer–Karnik (MSK) scale* from 1964,
- the twelve-stage *European Macroseismic Scale (EMS-92)* from 1992,
- the twelve-stage *European Macroseismic Scale (EMS-98)* from 1998.

These scales were used in Europe and that is why they will be considered in our analysis. The oldest of them: MM, MC, MCS were not used in LGOM, because they were adapted only to assess seismic occurrences (earthquakes). The MSK-64 scale was used in LGOM to assess the harmfulness of paraseismic influences (mining shocks). The EMS-98 scale is the next modification of the MSK-64 scale.

2.1. MSK-64 MACROSEISMIC SCALE

The MSK-64 scale is similar to the MM and MCS scales. It was approved in 1964 by UNESCO as the international standard in seismology. Evaluation criteria of the intensity of ground vibrations are the values of both acceleration and speed, describing the vibration effect on the surface and people's reactions assigned to each level of intensity. The description of possible results (damage to buildings) assigned to three designated groups of buildings with the amount of this damage is a complement to these criteria. The basic characteristic of the levels of intensity according to the MSK-64 scale, reduced to 8 most frequently used, is presented in table 1.

Table 1

Eight most frequently used levels of intensity (MSK-64 scale)

Level of intensity	Acceleration (mm/s^2)	Vibration characteristic
I	5÷12	unnoticeable
II	12÷25	very weak
III	25÷50	weak
IV	50÷120	moderate
V	120÷250	quite strong
VI	250÷500	strong
VII	500÷1000	very strong
VIII	1000÷2000	destroyable

The levels of vibration influence on people according to the MSK-64 scale can be itemized as follows:

Level of intensity I. Intensity of vibration is below people's threshold of perceptibility.

Level of intensity II. Vibrations are only noticed by very few motionless people in buildings, especially on higher floors.

Level of intensity III. Shock is felt inside houses by not many people and outside only in favourable circumstances. Vibrations are similar to those made by a passing light lorry. Attentive observers may notice small swings of hanging items, which are bigger on higher floors.

Level of intensity IV. Shock is felt by many people inside buildings and by a few outside. Some people can wake up but without a sense of fear. Vibrations are similar to those made by a passing heavy lorry. Windows, doors and dishes rattle. Furniture starts vibrating. Hanging items swing lightly. The shock can be noticed by people in parked cars.

Level of intensity V. Shock is felt by most people inside and outside buildings. Many sleeping people wake up and run outside. Buildings slightly vibrate. Hanging items swing noticeably and loose items can move. Open windows and doors can close and open on their own.

Level of intensity VI. Shock is clearly felt by most people inside and outside buildings. A lot of people are scared and run outside. Dishes made of glass and porcelain can break, books can fall off shelves and furniture can move.

Level of intensity VII. Most people are scared and run outside. Vibrations are felt by people driving cars. A lot of people have difficulties with their body balance.

Level of intensity VIII. Fear and panic dominate, even heavy furniture moves. People driving cars are visibly concerned.

In this scale, buildings are divided into 3 groups which refer to the influence of ground vibrations:

• group A (weak durability) – buildings made of crushed stone or green brick,

• group B (moderate durability) – simple/common buildings made of brick, ashlar or prefabricated elements,

• group C (high durability) – buildings with a monolith construction, made of reinforced concrete, concrete and strengthened wood.

In the area of damage, the types of them, ranging from the smallest to the biggest, are divided into:

• Level 1. Little damage, small cracks on plaster and small pieces of it fall off.

• Level 2. Medium damage, small fractures of walls, cracks on chimneys, bigger surfaces of plaster fall off, roof tiles fall down.

• Level 3. Heavy damage, deep and wide fractures of walls, the collapsing of high chimneys,

• Level 4. Local destruction, the collapsing of some parts of buildings.

Damage to buildings in each group regarding the level of intensity of ground vibrations are presented in table 2 (letter symbols relate to the amount of damage: p – singular, l – multiple).

Table 2

Damage to buildings in each group regarding the level of intensity of ground vibrations

Level of vibration intensity	Groups of buildings		
	A	B	C
I ÷ IV	lack of damage		
V	$p-1$	lack of diagnosis	
VI	$p-2$, $l-1$	$p-1$	lack of diagnosis
VII	$p-4$, $l-3$	$l-2$	$l-1$
VIII	$p-5$, $l-4$	$p-4$, $l-3$	$p-3$, $l-2$

The MSK-64 scale presented makes it possible to conclude that singular damage to buildings from group A, i.e. the group unusual in mining regions, appears at an acceleration higher than 120 mm/s^2. This value of acceleration can be considered as a limit of a harmful influence of ground vibrations on buildings. Because the acceleration of vibrations caused by mining shocks does not exceed 1000 mm/s^2, we can assume that mining shocks fit in the V, VI and VII levels of vibration intensity according to the MSK-64 scale. It is necessary to highlight that the magnitude of acceleration of ground vibrations according to the MSK-64 scale needs to be considered after filtrating these vibrations in the range of frequency up to 10 Hz. In the case of paraseismic activity, the evaluation of its effect on surface buildings, based on the parameters of the MSK-64 scale for mining shocks, can only be approximate because of the differences in the characteristics of earthquakes and mining shocks.

2.2. EMS-98 MACROSEISMIC SCALE

A final version of the EMS-98 scale was developed based on an earlier modification of the MSK-64 scale which was widely used for nearly 30 years. The first modification took place in 1981, the improved EMS scale in 1992 was recommended for use by the General Association ESC-1992 for the trial period. The next modifications of the EMS scale were made with the application of computer methods for estimating macroseismic data.

The modifications introduced improved this scale, but did not change its basic assumptions. In 1998, the European Seismological Commission (ESC) presented the newest version of the EMS scale, which was a result of close cooperation between seismologists and civil engineers. A shortcut version of the EMS-98 scale is presented in table 3. It is a big simplification which gives a general view of this scale. This form of the EMS-98 scale can be used for educational purposes. It cannot be used for practical assigning seismic intensity, because of the fact that this process requires precise analysis and demands appropriate procedures.

Table 3

A shortcut version of the EMS-98 scale

EMS intensity	Definition	Description of typical observed results (selected few)
1	2	3
I	unnoticeable	Unnoticeable.
II	slightly noticeable	Noticeable only by a few motionless people inside houses.
III	light	Noticeable only by a few people inside houses. Motionless people feel slight swinging and vibrating.
IV	noticeable	Noticeable by many people inside buildings, outside by only a few. Some people can be excited. Windows, doors and dishes start rattling.

1	2	3
V	heavy	Noticeable by many people inside buildings, outside by only a few. A lot of sleeping people wake up. Some are scared. Buildings shake. Hanging items swing. Small objects move. Doors and windows open and close.
VI	slightly damaging	A lot of people are scared and escape outside of buildings. Some items fall down. Many houses have damage not related to the construction such as cracks in and the falling off of some small parts of plaster.
VII	damaging	A lot of people are scared and escape outside of buildings. Furniture moves, many things fall off shelves. Many properly excavated buildings experience moderate damage such as: small cracks of walls, falling off of plaster, parts of chimneys falling down; old buildings can have deeper fractures in walls and greater damage in internal walls.
VIII	very damaging	A lot of people have difficulty to stand. Many buildings have big cracks in walls. A few properly excavated buildings show serious damage to walls and weak, old constructions can collapse.
IX	destructive	General panic. A lot of weak constructions collapse. Even properly excavated buildings experience severe damage such as: serious damage to walls and partial constructional damage.
X	severely destructive	A lot of properly excavated buildings collapse.
Xl	devastating	Most properly excavated buildings collapse, even those with good quake resistance.
XlI	totally devastating	Nearly all buildings collapse.

3. EMPIRICAL SCALES FOR PARASEISMIC INFLUENCE

For mining regions, the LGOM formulated one empirical scale, i.e. the GSI-2004 scale, which applies to mining shocks. This scale was created on the basis of long experience gained in the area of LGOM with dynamic influences of mining shocks.

3.1. GSI-2004 MINING SCALE OF INTENSITY

It was formulated in the Central Mining Institute in Katowice and is currently implemented into the LGOM. The authors of this scale presented three independent criteria of the harmfulness of vibrations based on:

- maximal acceleration spectrum of SA answer,
- resultant amplitude of the speed of horizontal vibrations, $PGV_{H\max}$,
- acceleration amplitude of the horizontal component of vibrations in the frequency band up to 10 Hz, PGA_{H10}.

Parameters which should be taken into account are: the frequency of free vibrations for the GSI-2004-S scale and the time of vibrations for the GSI-2004-V and GSI-2004-A scales. In these scales, the dynamic characteristic of the object and also the time of the mining shock occurrence, which in different scales has so far been omitted, are taken into account. The scale includes real results of shocks observed in compact settlements, which took place in particular mining plants of the KGHM. This scale, in a significant way, makes the assessments of the level of harmfulness achieved in analytic research more comparable to the natural state.

This scale in the period between 2004 and 2006 was modified and implemented in the mining regions of the LGOM, based on real observations of buildings and the analysis of mining shock occurrences. In this period of time, the Commission of Surface Protection in WUG (State Mining Authority) in Katowice was assessing this scale based on reports from chosen scientific centres and changes introduced by authors of this scale. In its last meeting on June 9th, 2006, the Commission of Surface Protection passed the resolution (No. 2/2006) on the purpose of using this scale under LGOM conditions. The GS1-2004 scale was officially introduced in the document with the title of “The instruction of leading seismic measurements on the surface, interpretation of results and assessing the forecasting of seismic vibrations caused by mining shocks in the LGOM area, based on the GSI-2004 scale”. The use of instruction was made obligatory on September 20th, 2006, by the Chairman of KGHM PM S.A. in the Organisational Agreement No. PG/1/2006.

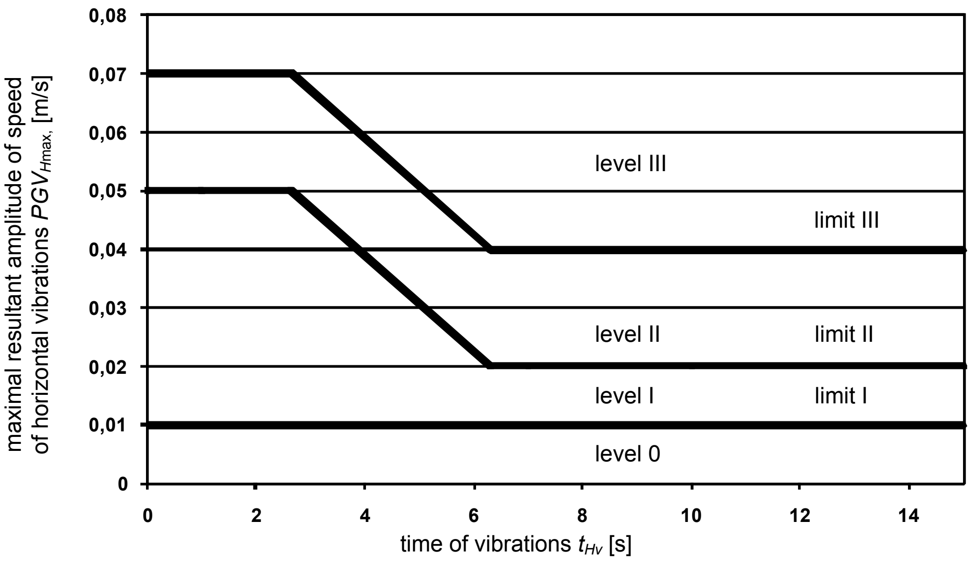

Fig. 1. GSI-2004-V scale

The parameters necessary to assess vibration harmfulness are: the maximal value of resultant horizontal amplitude of vibration speed $PGV_{H\max}$ or PGA_{H10} and also the time of vibrations t_H of a horizontal component. These parameters (figure 1) can be calculated based on:

- real course of vibrations in places of their registration,
- local empirical dependencies.

Level 0

Influence of vibrations intensity on buildings: Shocks do not cause any damage to buildings. The parameters of vibrations from shocks in the buildings are similar to those of local vibrations caused by everyday life activity (moving around a flat, slamming doors, drilling in walls, etc.) and the parameters of ground vibrations are similar to those of vibrations caused by motor traffic.

Influence of vibrations intensity on linear objects of underground infrastructure: Vibrations are harmless for linear objects of underground technical infrastructure. The parameters of vibration affecting those objects are similar to those caused by the motor traffic on roads.

Perceptibility of vibrations by people: Insignificant/noticeable. Shocks occurring in a low part of level 0 are nearly imperceptible to people. Shocks in the top range of level 0 are slightly perceptible to people.

Nuisance: Unnoticeable/small.

Level I

Influence of vibrations intensity on buildings: Shocks do not cause any damage to buildings. In some cases, unstable, small and light items and decorations can fall down (e.g., thin figurines placed on shelves; tall, not stable vases, etc.). Open windows and doors can close. Furniture may shake and hanging items can swing. Possible development (an increase of intensity) of existing cracks, fissures and other damage.

Influence of vibrations intensity on linear objects of underground infrastructure: Vibrations are harmless for linear objects of underground technical infrastructure.

Perceptibility of vibrations by people: Noticeable/causing adverse reactions. Shocks can be strongly felt on the surface, especially by people on higher floors during the shock.

Nuisance: small.

Level II

Influence of vibrations intensity on buildings: Whole buildings can shake. Shocks can cause damage to the elements of interior trim of buildings. The most typical damage may be itemized as follows: the falling off and cracking of wall tiles, cracks around door and window reveals, the cracking of glass, the cracking or fracturing of partition walls, the cracking and fracturing of plaster. Sometimes damage to roof tiles and cracks on the elevation can be seen. There can be some small damage to individual items: the falling of small, separately standing items (e.g., books, figurines, etc.), the breaking of dishes and glasses. Furniture can shake and in some cases can slightly move.

Influence of vibrations intensity on linear objects of underground infrastructure: In some cases, vibrations can be harmful to linear objects of underground technical infrastructure, especially in old installations around joints.

Perceptibility of vibrations by people: Causing adverse reactions. Shocks are strongly felt by all people inside and outside buildings. Vibrations with this intensity can wake people up. Some people feel fear during the vibrations.

Nuisance: moderate.

Level III

Influence of vibrations intensity on buildings: In this case, we can deal with all the consequences described in level II and also with damage such as: the loosening of cornices, the falling down of roof tiles, the loosening of plaster, the damage to chimneys, damage to gable walls in brick buildings and cracks in bearing walls. More serious damage can occur to individual items: the moving or falling down of furniture (especially thin-wall units on higher floors), the falling down of picture frames and bigger items (e.g., TV sets).

Influence of vibrations intensity on linear objects of underground infrastructure: Vibrations can be harmful to linear objects of underground technical infrastructure, especially in old installations around joints.

Perceptibility of vibrations by people: Tiresome/causing fear. Shocks are very strongly felt by all people inside and outside buildings. People are scared and experience severe discomfort. Some people, especially living on higher floors, run out of buildings.

Nuisance: great.

Notes/recommendations for the GSI-2004-V scale: It is recommended that we should not to go beyond a small nuisance. It is possible to allow a moderate or great nuisance; however, then it needs to be justified on the grounds of technical and economical reasons and achieves appropriate agreements. Each shock classified into the III level of intensity, because of its potential danger, requires an individual assessment, and the effect of its vibrations on buildings has to be determined by a qualified civil engineer. During recent mining extraction run in the LGOM, the results of local damage to buildings (collapsing parts of building, stand-alone chimney, etc.) were not seen. There were only the results described for each level of the intensity registered.

3.2. GS1-2004-A SCALE

This scale can be used for historical data in regions where shocks have not been directly registered in the past; however, the parameters of vibrations in the form of maximal amplitudes of the vibrations acceleration PGA_{H10} in the range up to 10 Hz were calculated based on local empirical dependencies. In order to assess shocks, the following parameters are indispensable: the maximal amplitude of horizontal vibration acceleration PGA_{H10} and the time of the horizontal component of the vibrations' acceleration t_H. It is acceptable to calculate the time of vibrations t_H from empirical dependencies representing a seismic energy shock E_s and the potential distance R. The GS1-2004-A scale is used to exploit a set of archival information about vibration accelerations determined in the area of interest. It also gives an opportunity to compare current assessments based on the GSl-2004-V scale with earlier ones based on the parameter of acceleration. This scale includes 4 levels of intensity, for which the influence of mining shocks on buildings and linear objects of underground infrastructure and also an intensity of vibrations felt by people and the nuisance of using buildings are described. The description of the levels of intensity is identical for all GSI-2004 A, V, S scales (figure 2).

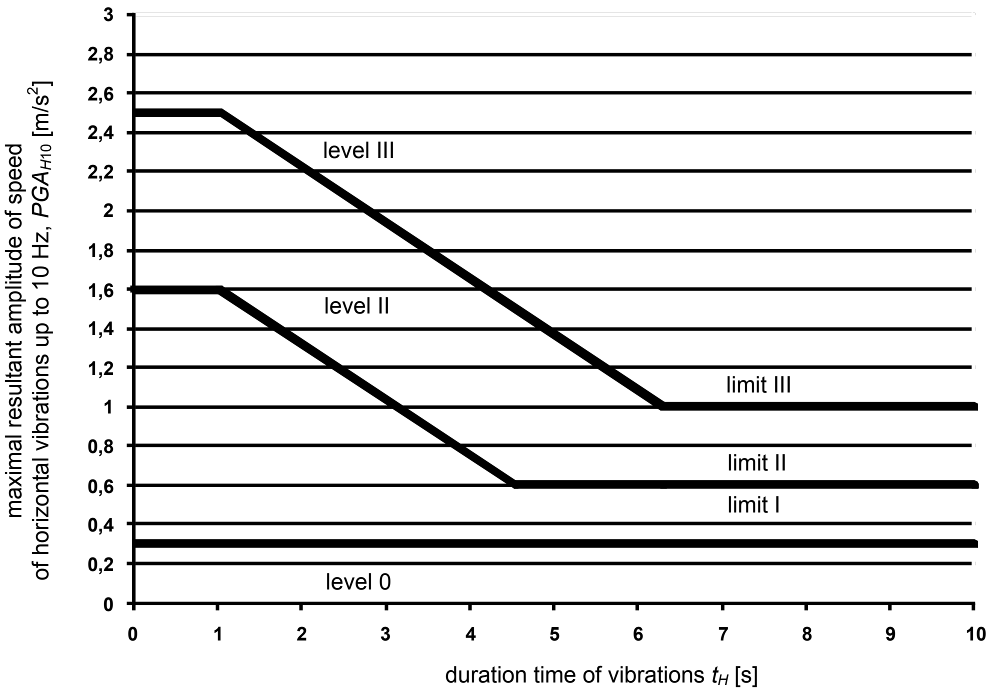

Fig. 2. GSI-2004 A, V, S scales

Due to these scales the damage to surface buildings is classified into appropriate levels of seismic intensity.

4. AN EXAMPLE OF RESULTS FROM THE STRONGEST SHOCKS IN O/ZG RUDNA IN 2000–2007 BASED ON THE GSI-2004 SCALE

Shocks whose energy exceeds 1.0×E8 Joule are considered to be the strongest mining shocks. Their results on the surface can be similar to those of seismic occurrences. Damage to surface buildings can be radically different from that after earthquakes; however, only at this level of mining shock energy, we can compare these two occurrences in terms of the parameters of ground vibrations and also the influence on the surface. In this case, MSK-64 scale is most appropriate for such comparisons because it had been used in the LGOM for many years before the GSI-2004 scale was discovered. Another similarity in these scales is the fact that they use the parameters of ground vibrations determined by the values of the acceleration and speed of these vibrations. An analysis of this comparison made for the strongest mining shocks will include, in the final stage, a specific diversity of these scales which is a result of differences between paraseismic and seismic occurrences. In the period between 2000 and 2007, 18 mining shocks whose energy exceeded 1.0×E8 Joule were registered (figure 3).

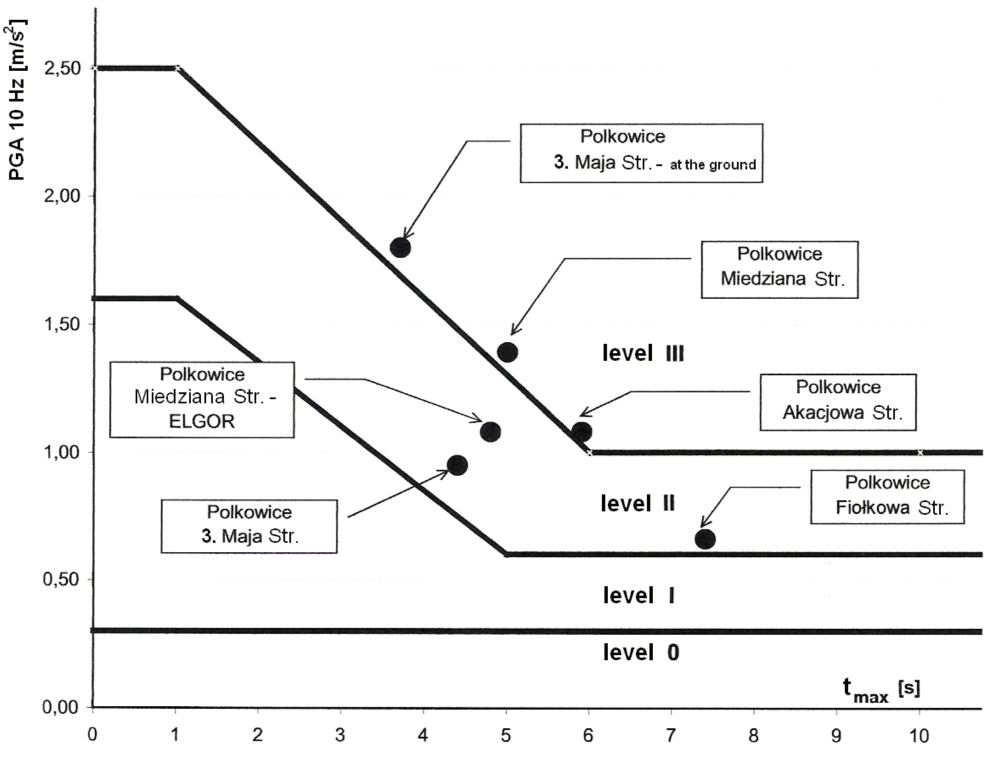

Fig. 3. Examples of shocks in GSI-2004 scale, location: Polkowice, the 3. Maj Street, Miedziana Street, ELGOR: 1.5×E8 J (Joule), the 3. Maj Street, ground, Miedziana Street: 8.4×E8 J (Joule)

5. ADVANTAGES OF EMS-98 SCALE IN RELATION TO GSI-2004 SCALE

The EMS-98 scale has been being created for the last 40 years based on global experience gained from earthquakes all over the world. During these years, the scale, in terms of the criteria of assessing the harmful influence of earthquakes on surface buildings, was significantly modified. It can be said that, to some extent, it is an empiric scale because of using wide experience in this field. There are also fundamental differences between EMS-98 and GSI-2004 in terms of the responsibility for earthquakes and mining shocks. The former are connected with the forces of nature, which are not and never will be completely predictable. The latter are connected with exploration and economic activity of man and for this reason they and their influence on buildings should be correctly described.

The EMS-98 scale has some significant advantages over the GSI-2004 scale due to the issues considered and dealt with the assessment of harmful influence of mining shocks on surface buildings.

5.1. TYPES AND KINDS OF BUILDINGS

The description of the types of buildings and the types of materials used is comprehensive. They are generally divided into brick, reinforced concrete, steel and wooden constructions. The most developed type are brick buildings, of which the buildings made of stones and brick with elements of reinforcement have been described. The next group form buildings with a reinforced concrete construction with established schemes of walls and frames. In addition to this, the division of constructions protected from seismic influences (ERD) have been introduced. Only in steel and wooden constructions a more detailed division has not been made. The class (A–F) of building resistance to damage connected with the seismic influences, from the smallest (the weakest) to the greatest susceptible (the strongest) has been assigned to each type of construction. The next advantage lies in the possibility of assessing the probability that the class of resistance of each type and kind of construction to damage is appropriate. In relation to the GSI-2004 scale, in which there is no division into the types of building constructions and the only suggestion refers to the reduction of the height of buildings to 12 storeys, it is a very meritoriously advanced division which aims at simplifying the procedures of qualifying the results to appropriate levels of intensity.

5.2. A DETAILED DESCRIPTION OF DAMAGE OR DESTRUCTION IN BUILDINGS

The description of damage and destruction in buildings divided into five classes of their resistance to damage (from A to F) is a quite precise way of assessing the possible results of each level of seismic activity. It allows better classification of seismic occurrences into the levels of their intensity. This approved way of assessing results, as a specified procedure of diagnosis which includes real results in different types of buildings, enables us to remedy serious mistakes in the classification of the level of seismic intensity. In relation to the GSI-2004 scale, such a way of diagnosis is far more developed and accurate, because it is based on criteria regarding the classification procedure. The GSI-2004 scale offers only a descriptive form of damage to buildings, which is an addition to the classification based on the parameters of ground vibrations, calculated by empiric formulas or measured on seismic and metrical posts in the terrain.

5.3. A DESCRIPTION OF THE PERCEPTIBILITY BY PEOPLE

The description of the perceptibility of seismic occurrences in the EMS-98 scale is very similar to the descriptions based on the GSI-2004 scale, for comparative levels of intensity. The description of people's reactions to these occurrences in the EMS-98 scale comes to an end on IX level, which is called the *destructive level* (global panic, people can be prostrated). At the higher levels there are no descriptions because of understandable reasons. In the GSI-2004 scale, the term *nuisance* was introduced, specified as unnoticeable, small, medium or big on each level of intensity. It gives a slight unidentified view of the harmfulness of mining shocks.

5.4. A DESCRIPTION OF EFFECTS ON MOVING OBJECTS

This description in both scales is very similar, quite widely formulated, and there are no special advantages of using the EMS-98 scale compared to the GSI-2004 scale.

5.5. IMAGINARY WAY OF PRESENTING RESULTS FOR SURFACE BUILDINGS

The description of damage and destruction on each level from 1 to 5 in the EMS-98 scale is supplemented by pictures – drawings, which symbolically illustrate specified types of damage. Such a graphic classification is made for brick constructions and separately for reinforced concrete constructions. It is a very helpful for specifying the levels of intensity. The GSI-2004 scale does not offer such possibilities.

5.6. ELEMENTS OF ASSESSING PROBABILITY

In the EMS-98 scale, this issue was considered very seriously. First of all it refers to the classes of resistance of buildings to damage defined as A, B, C, D, E, F for each type of building as follows:

the most probable,
probable,
less probable.

The probability of damage is assessed in the range of a few classes of resistance. The elements of probability are also included in the assessment of damage and destruction for excluded levels of intensity a, b and c. It is a global view of occurrence probability in relation to an appropriate level of the harmfulness of the influence of earthquakes on surface buildings. In the GSI-2004 scale, there is no possibility of assessing the probability of damage, depending on the types of buildings or level of seismic intensity. The only relation of probability to this issue is a definition that after classifying the level of intensity based on the parameters of ground vibrations, the damage described in this level can occur, but does not have to. Such a level of assessment seems to be insufficient.

5.7. REFERENCES TO STANDARDS AND INSTRUCTIONS

The EMS-98 [1] scale refers in its diagnostic procedure to the international seismic standard Eurocode-8, indicating some helpful establishments of this standard in the designing of building constructions. The GSI-2004 scale, despite the fact that in standard references there are the Eurocode-8 and PN-85/B–02170 mentioned and also Polish instructions from the Building Research Institute of Warsaw and Central Mining Institute of Katowice, it does not refer in its content to these documents, indicating specific recommendations in chosen issues.

6. SUMMARY AND CONCLUSIONS

The comparison of the macroseismic EMS-98 scale with the empirical GSI-2004 scale, although they refer to different occurrences, i.e. earthquakes and mining shocks, respectively, makes it possible to choose a group of common issues. This group of issues is clearly specified in this paper and makes the comparison of the intensity of these two scales in the area available to specify possible. At the lowest levels of intensity, this comparison is valid. It seems to be completely justified because of a very low level of dynamic effects.

The minimal seismic effects (levels I and II) are closely comparable with paraseismic effects from mining shocks. It can also be inferred that a higher level of seismic effects (levels III and IV) compares well with paraseismic influences on the level I of seismic intensity. The level V of intensity in the EMS-98 scale, in terms of description of this intensity effect on buildings, is also quite similar to the level II in the GSI-2004 scale. Even if the descriptions of damage to buildings sometimes differ, the descriptions of people's and moving item reactions make these two levels of intensity closer. The levels VI and VII of intensity in the EMS-98 scale can only be approximated to the level III of intensity in the GSI-2004 scale.

Damage from the level VII of intensity in the EMS-98 scale is significantly greater than that generally described in the level III of intensity in the GSI-2004 scale. This can be partially explained by the fact that the level III of intensity in the GSI-2004 scale did not allow exact description of damage or potential destruction in buildings. Such a level of intensity has only been estimated for 3 of the strongest mining shocks in the mining region O/ZG Rudna in the years 2002, 2004 and 2006 with energy exceeding the threshold of 1×E9 J (Joule). Therefore, the experience and descriptions of the effect of seismic activity on the earth's surface are significantly limited. In the area of this influence on people, the levels VI and VII seem to be visibly higher than the level III of intensity in the GSI-2004 scale. The intensity reaching the level VIII in the EMS-98 scale cannot be compared with the intensity in the GSI-2004 scale, because the effects of seismic activity on the earth's surface in the level VIII of the EMS-98 have a destructive and devastating character which is not defined in the empirical GSI-2004 scale.

Exceptional advantages of the macroseismic EMS-98 scale should be the basis for making some improvements and for developing some areas in the GSI-2004 scale in order to correct or even to establish a special procedure for diagnosing damage or destruction in buildings and to set the levels of intensity. Firstly, it refers to such issues as:

- the development in the number of types and kinds of buildings,
- the establishing of the descriptive levels of damage due to special levels of damage and special types and kinds of buildings in the special ranges of intensity,
- the formulation of the limits of occurrence probability of the effects on surface buildings,
- illustrating with pictures or drawings some typical damage to buildings on the special levels of intensity.

Verification and also improvement of the GSI-2004 scale, as described above, are strongly recommended by the authors.

REFERENCES

[1] GRUENTHAL G. (ed.), *European Macroseismic Scale 1998*, [in:] *Conseil de l'Europe Cahiers du Centre Européen de Géodynamique et Séismologie*, Vol. 15, Luxembourg, 1998.