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THE PROTECTION OF BUILDINGS FROM METHAN COMING OUT OF BEDROCK

OCHRANA STAVEB PROTI METANU VYSTUPUJÍCÍMU Z PODLOŽÍ

Abstract

On the surface of the Earth, methan is usually located in undermined areas, especially in places where the mining was stopped already. The protection of buildings from methan coming out of bedrock can be provided by layer isolation made of suitable type of polymer foil. The entry deals with the matter of designing the isolation against penetrating methan coming out of bedrock into surface line buildings (e.g. shaft, reservoir, water tower etc.).

Keywords

Undermined area, methan, insulation against infiltration of methan.

Abstrakt

Metan se vyskytuje na zemském povrchu zpravidla na poddolovaném území, zejména v lokalitách, kde již bylo hlubinné dobývání ukončeno. Ochranu podzemních liniových staveb proti pronikání metanu z podloží zajistíme povlakovou izolací z vhodného typu polymerní fólie. Příspěvek pojednává o problematice návrhu izolace proti pronikání metanu z podloží do podzemních liniových staveb (např. kolektorů, šachet, jímek, zásobníků, vodojemů apod.).

Klíčová slova

Poddolované území, metan, izolace proti pronikání metanu.

1 INTRODUCTION

Methane exists on the earth surface generally on undermined territories, mainly on sites where the underground mines have been abandoned. Typical sources of the methane are the abandoned mine workings without ventilation where the mine gas penetrates through the permeable overlying strata onto the earth surface. In accordance with ČSN 73 0039 [1], the undermined territories are the sites within the effects of the underground mining.

The problem is that the mixture of the methane and air may create an explosive or flammable concentration. The explosive concentration of the methane ranges between 5 and 15 %, depending on the contents of the gas in the air mixture.

Territories where the mine gas escapes are divided into following categories:
A – territories with the possible random escape.
B – territories jeopardised with the escape.
C – territories with hazardous escapes.
D – blown-outs from Carboniferous formations.

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E – territories close to the abandoned mine working or close to the main mine workings or mining drills that are being liquidated now.

Constructions are divided into following categories by the degree of threat of the escaping mine gas:

a) level 1 - safe construction. The measured concentration of methane does not exceed 0.1% anywhere,

b) level 2 – endangered construction. The measured concentration of methane exceeds 0.1%, but is below 0.5%,

c) level 3 – dangerous construction. The measured concentration of methane exceeds 0.5%.

If the methane escapes from the subsoil and the concentration of the methane in the soil air varies considerably in dependence on the barometric pressure, and the methane penetrates through the contact structures (such as the floors and external walls into the buildings), it is essential to take constructional actions to limit the blow-outs dramatically. It is necessary to ensure that throughout the service life of the constructions, the concentration of the methane inside the buildings will be below the limit value of 0,1% that is a warranty for a safe operation of the constructions.

2 METHANE PROTECTION ACTIONS

The actions preventing the penetration of the methane from the bedrock into the constructions are different for:

1. **New constructions.**
2. **Existing constructions.**

Both the new constructions and existing constructions can be **M-type** constructions where the mine gas may collect –such as closed buildings, underground structures, or service tunnels) or N-type constructions where the collection of the mine gas is excluded (such as open structures, or lineal aerial structures). **The methane prevention actions are proposed only for the M-type constructions. For the N-type constructions, the preventive actions are not necessary** if technically possible the preventive actions should be performed irrespective of the user of the construction.

The actions preventing the penetration of the methane into the constructions are based on the atmo-geochemical measurements of the methane concentration in the soil air. The measured concentration is indicated in the layout that gives the varying values in different plane views – see Fig. 1.

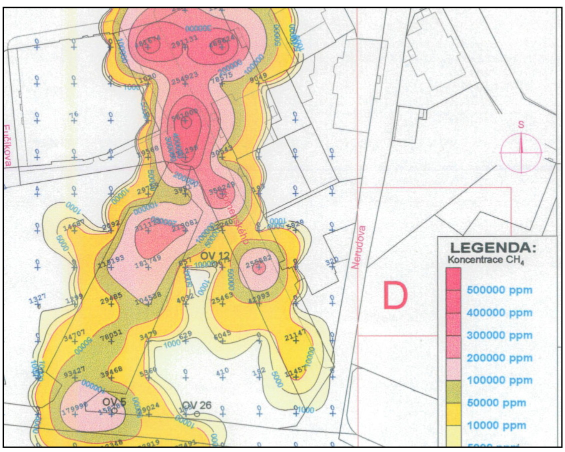

Fig. 1: Sample of the layout map with the different methane concentrations in the soil air

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3 PREVENTIVE ACTIONS FOR NEW CONSTRUCTIONS

Two basic constructional actions exist for the new constructions:

1. Coated insulation against the leakage of methane.

2. Location of the entry floor above the ground level. It is necessary to exclude absolutely the contact of the entry floor with the bedrock. The principle is shown on Fig. 2.

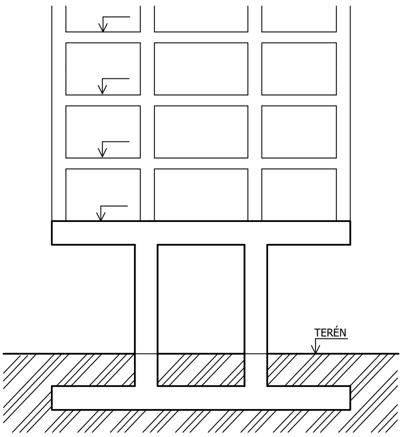

Fig. 2: An example of the building with the entry floor above the ground level

In both cases, the internal sewage pipes must be gastight (and must be tested in accordance with ČSN 73 6760 [6]). The ventilation head of the internal sewage system must be in such a height above the level of the roof so that any manipulation with an open fire there (for instance, a repair of the roof or tin-smith components in the future) **would be excluded.** This requirement can be also met by any other method that is in line with the respective safety regulations.

All underground structures (such as the foundation constructions or inspection manholes) **must exclude a possibility of methane accumulation.**

If any of the methods above is used, it is essential to install in the contact floor of the building a device that will record the data about the presence of the mine gas and methane (CH_4) as well as the numbers of the respective sensors. The recorder must be connected to a central security system that will inform a service team as soon as the concentration is too high. The service team will take corrective actions (typically, an intensive ventilation).

3.1 Coated insulation against the leakage of methane from subsoil

The coated insulation against the leakage of methane from the bedrock is used for the structures of the contact floor that touches the bedrock (the floor or vertical external walls of the lowers floor). This will also ensure that the requirements set out in Section 7.2.1, ČSN 73 0540 - 20 will be fulfilled, this means that the lowest exchange of the air in the unused room will be $n_{min,N} = 0.1\ h^{-1}$. The reason is to prevent accumulation of the methane inside the building/room if the building or certain rooms are closed or unused for a rather long time. The barrier insulation decreases dramatically the diffusion of the methane through the contact structure inside the building, depending on the diffusion coefficient D [$m^2.s^{-1}$] for the methane.

When applying the coated insulation it is recommended to take following supporting measures:

1. To minimise the subsoil-construction contact, if possible.
2. To cover the ground structures with high gas permeability materials, for instance gravel soil or sand soil, G1, G2, G3, S1, S2, S3 classes pursuant to ČSN 73 1001 [4].Not to use materials with low gas permeability (such as asphalt or concrete) in big areas or for landscaping, above the underground structures and in close neighbourhoods.

3.2 Sizing the thickness of the coated insulation against methane leakage

The type and thickness of the coated insulation against methane leakage depends on the requirements above (see above). This means, all specific aspects should be taken into account and a comprehensive evaluation is necessary.

The thickness of the coated insulation can be calculated using the procedure below which was developed on the bases of [5] where the formulae (2) and (4) were mentioned. Using this method it is possible to design the minimum necessary thickness of the insulation, $b_{min.}$, [m] so that the methane weight flow intensity, $Q_{m,}$ through the insulation into the structure were less than the maximum permitted weight flow intensity, $Q_{m,\ max}$.

The thickness of the coating insulation is proposed for one room. It is almost the worst-scenario room in a contact floor which is chosen.

a) The worst-scenario room is the room with the highest value of P [m]:

$$P = \frac{A}{V} \quad [\mathrm{m}^{-1}] \tag{1}$$

where: A [m^2] – the total area of the structure which is in contact with the subsoil – see formula (3),
V [m^3] – the total volume of the room

If the methane insulation thickness were designed using the real intensity of infiltration ventilation for the room n [–], the calculation method should be in line with ČSN 06 0210 [3]. The worst scenario room should be then classified again using that criterion, the lowest intensity of infiltration ventilation being n [–], similarly as in design proposals of radon insulation pursuant to ČSN 73 0601 [7]. In that case, $\boldsymbol{n}$ **= 0.05 h^{-1}** (see below) is always chosen in order to ensure the safety.

b) The minimum necessary thickness of the insulation, $b_{min.}$ [m], against methane leakage is obtained from:

$$b_{\mathrm{min.}} = D_m \cdot \frac{A \cdot (v_1 - v_2)}{n \cdot V \cdot v_2} \quad [\mathrm{m}] \tag{2}$$

where: D_m [m^2.s^{-1}] – the methane diffusion coefficient
v_1 [%] – the concentration of methane leaving the subsoil
v_2 [%] – the maximum permitted concentration of methane downstream the insulation (inside the structure)
A [m^2] – the total area of the structure which is in contact with the subsoil – see formula (3)
V [m^3] – the total volume of the room
n [s^{-1}] – intensity of infiltration ventilation in the room

The values below are substituted in (2):
– $\boldsymbol{v_2}$ **= 1.10^{-3} , this means 0.1 %** (see Chapter 1).
– $\boldsymbol{v_1}$ will be replaced as follows:

a) With **10%** in the **A** category sites.
b) With a double of the value measured as a reference value for the design in the **B** through **D** category sites. With at least 10 % but not more than 100 %.
c) With **100%** in the **E** category sites.

– $\boldsymbol{D_m}$ **[m^2.s^{-1}]** will be chosen for a specific insulation material. The value to be used will be the worst one (i.e. the higher one) from the values measured in the surface and in the joint.

– For safety reasons, $\boldsymbol{n}$ **= 0.05 h^{-1} (*n* = 1.39 . 10^{-5} s^{-1}).** This means, the value will be a half of $n_{min,a}$ = 0.1 h^{-1}.

The total area of the structure which is in contact with the subsoil, *A* [m^2], is calculated as follows:

$$A = A_p + A_s \text{ [m}^{-2}\text{]} \tag{3}$$

where: $\boldsymbol{A_p}$ [**m**^{2}] – the surface of the floor which is in contact with subsoil,

$\boldsymbol{A_s}$ [**m**^{2}] – the total area of all walls which are which in contact with adjacent soil.

d) **b) The time, $\boldsymbol{t_k}$ [s], during which the methane concentration goes up beyond the critical methane concentration, $\boldsymbol{v_{2,krit.}}$ = 4 %, can be calculated from the following formula:**

$$t_k = \frac{V \cdot b}{D_m \cdot A} \cdot \ln \frac{v_1 - v_2}{v_1 - v_{2,krit.}} \text{ [s]} \tag{4}$$

where: b [m] – the designed real insulation thickness,

$v_{2,krit.}$ [%] – the critical concentration of methane. $v_{2,krit.}$ = 4 % is always substituted there.

Description of other quantities is given in (2). The time, t_k , is calculated with the assumption that ventilation intensity is $n = 0$.

The following condition must be fulfilled:

$$t_k \geq 90 \text{ days} \tag{5}$$

3.3 An example: designing the coated insulation against leakage of methane from subsoil

Let us take a new detached house with a cellar under its full surface. For the ground plan see Fig. 2. For the cross-section see Fig. 4. The house is located in a flat surface and is immersed in such a way that the upper surface of the floor contact layer in the basement is located 1.0 m under the landscape.

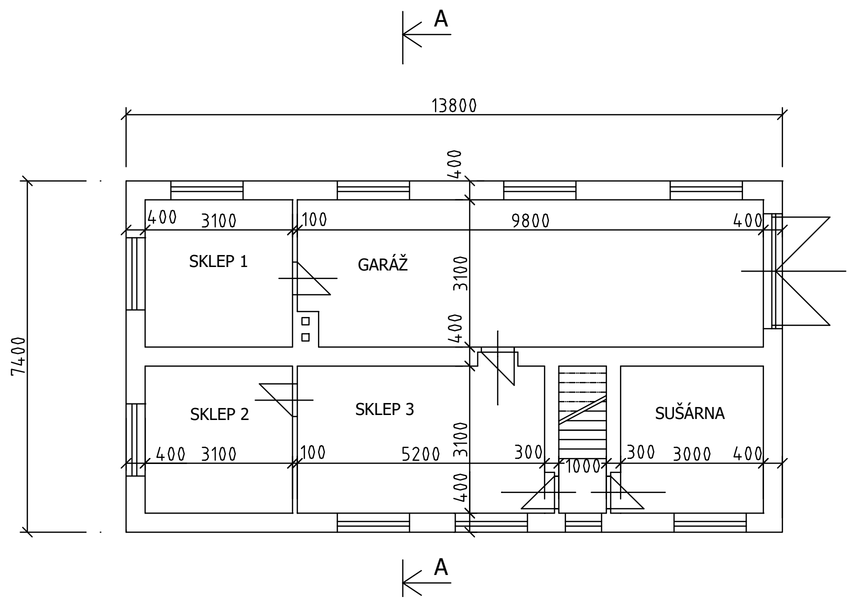

Fig. 3: Ground plan of the detached house basement

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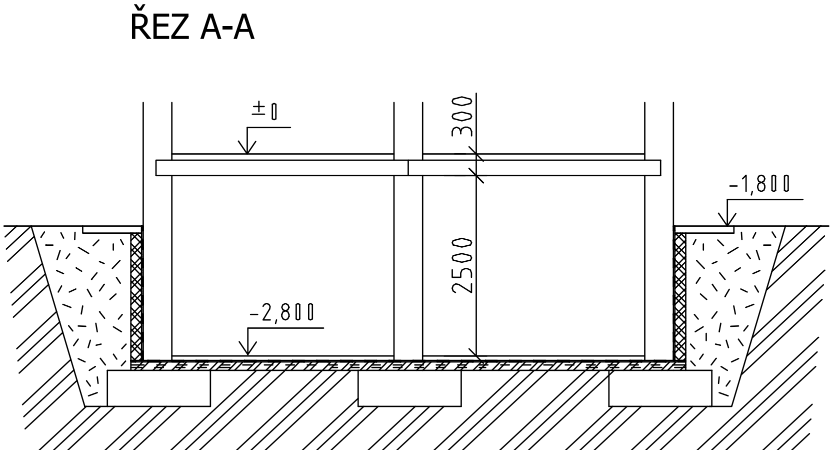

Fig. 4: Cross-section, A-A

1. Choosing the room

The room used for the calculation will be a laundry hanging room because *P* [m] of its surface in the basement is the highest.

The total volume of the room: $\boldsymbol{V} = \mathbf{3.0 \times 3.1 \times 2.5 = 23.25\ m^3}$

The total area of the structures which is in contact with the subsoil:

$$A = A_p + A_v = 3{,}0.3{,}1 + 3{,}0.1{,}0 + 3{,}1.1{,}0 = 15{,}40\ \mathrm{m}^2$$

$$P = \frac{A}{V} = \frac{15{,}40}{23{,}25} = 0{,}66\ \mathrm{m}^{-1}$$

2. Let us calculate the minimum necessary thickness of the insulation, *b* [m]:

The calculated ventilation intensity: $\boldsymbol{n} = \mathbf{0.05}\ \boldsymbol{h}^{-1} = \mathbf{1.39.10^{-5}}\ \mathrm{s}^{-1}$-, $\boldsymbol{v_1} = \mathbf{1{,}0}$, $\boldsymbol{v_2} = \mathbf{0{,}001}$.

The proposed polymer foil – PE-HD Penefol 950 (produced by VK Lithotex, a. s. Žďár nad Sázavou)**.** : The diffusion coefficient for methane, D_m:

a) In the foil surface (without the connection) – $\boldsymbol{D_m} = \mathbf{3.461.10^{-12}\ m^2.s^{-1}}$,

b) In the connection – $\boldsymbol{D_m} = \mathbf{4{,}223.10^{-12}\ m^2.s^{-1}}$.

$$b_{\mathrm{min.}} = D_m \cdot \frac{A \cdot (v_1 - v_2)}{n \cdot V \cdot v_2} = 4{,}223.10^{-12}.\frac{15{,}40.(1-0{,}001)}{1{,}39 \cdot 10^{-5} \cdot 23{,}25 \cdot 0{,}001} = 2{,}0.10^{-4}\,\mathrm{m} = 0{,}2\ \mathrm{mm}$$

We will choose the minimum available thickness of Penefol 950: ***b*** **= 0.6 mm**.

3. The time, t_k [s], during which the methane concentration in the room goes up beyond the critical methane concentration, $v_{2,krit.}$ = 4 %, (when n = 0) is:

$$t_k = \frac{V \cdot b}{D_m \cdot A} \cdot \ln \frac{v_1 - v_2}{v_1 - v_{2,krit.}} = \frac{23{,}25.0{,}6.10^{-3}}{4{,}223.10^{-12} \cdot 15{,}4} \cdot \ln \frac{1 - 0{,}001}{1 - 0{,}04} = \mathbf{8\,541\,810\ s = 98{,}8\ days > 90\ days} \Rightarrow$$

the proposed foil thickness, *b* = 0.6 mm, is **compliant.**

4 PREVENTIVE ACTIONS FOR EXISTING CONSTRUCTIONS

The source information for proposing the protection actions against methane leaking from the subsoil is investigation and survey of the construction. Attention needs to be paid to following aspects when surveying the existing construction in the fire dump site:

a) **Measuring the interior methane concentration.**
b) **Conducting a building and technical survey.**
c) **Conducting a moisture survey.**

The **interior methane measurements** can be done only by an accredited testing laboratory in line using methods approved by the Czech Accreditation Institute. The measurement is carried out upon a request of a company which is responsible for remediation and removal of mining consequences or upon a request filed by the owner of the construction.

The building and technical survey consists of following steps:

a) Evaluation of the documentation. If the documentation is available, it is necessary to check whether it is in line with reality. If the documentation is not available, surveying should be carried out and the real situation should be documented.

b) Visual inspections of all contact surfaces (the external walls and floor constructions in contact floors) in order to identify static failures, if any, in contact structures, or places where methane escapes into the building.

c) Probes, if necessary, in contact constructions in order to identify the composition/properties of the contact constructions.

The **moisture investigation** is carried out pursuant to ČSN P 73 0610 [8] if too much moisture is identified in vertical constructions or floors in the contact floor level.

The investigation results should be properly documented and presented in expert opinions, which, in turn, are the basis source information for preparation of the project documentation for subsoil methane protection of the construction.

If static failures are found in the contact constructions, improvements and underpinning should be carried out within the subsoil methane protective actions.

If high moisture is found in the contact constructions during the moisture investigation, moisture should be removed from the contact construction within the subsoil methane protective actions. Such actions should be in line with ČSN P 73 0610 [8].

In case of **underground constructions**, following actions are also needed to eliminate leakage of methane from the subsoil into the building:

a) Sealing of each crack in external walls, partition walls and in the bottom of the contact floor.
b) Sealing each hole through the external walls and bottoms of the contact floor.
c) Sealing all inspection holes for internal sewage pipes.
d) Making all floor inlets gas proof.
e) Making all expansion joints gas proof.
f) Making internal sewage pipes gas proof and taking proper ventilation measures.

In case of the **existing constructions**, it is possible, depending on specific conditions (such as the frequency of occurrence of higher methane concentrations in a contact floor or size of measured values or methane concentration in soil air), to use any of the two available methods:

1. Additional coated insulation against the leakage of methane.
2. Modifications in the contact floor ventilation.

4. 1 Additional coated insulation against the leakage of methane.

The additional coated insulation against the leakage of methane from the subsoil is used for the structures of the contact floor that touches the bedrock (the bottom or vertical external walls of the lowers floor). 7. 2. 1 This will also ensure that the requirements set out in Section 7.2.1, ČSN 73 0540 - 20 will be fulfilled, this means that the lowest exchange of the air in the unused room will be $n_{min,a}$ = 0,1 h^{-1}. This procedure is same as in the new constructions (see Chapter 2.1), the difference being that the designed insulation is installed additionally and is applied onto the vertical constructions up to the minimum level of 300 mm above surface of the contact layer of the new floor next to inside walls or at least 300 mm above the level of the adjacent landscape. The insulation at the vertical walls must be gas proof (see details A, B and C in Fig. 5). Holes through the insulation must be gas proof as well. The principle is shown on Fig. 5.

If there is not horizontal protection against ground moisture or if this protection does not work well, it is essential to design the horizontal methane protection in order to prevent increased penetration of the ground moisture into vertical constructions. This may be the consequence of the situation when the ground moisture which diffused through the floor into the building starts accumulating under the vertical protection and penetrating, in turn, into adjacent vertical constructions.

Should the methane protection be used also as a ground moisture protection or as improvement measure against too high moisture of contact structures, a more general approach would be needed.

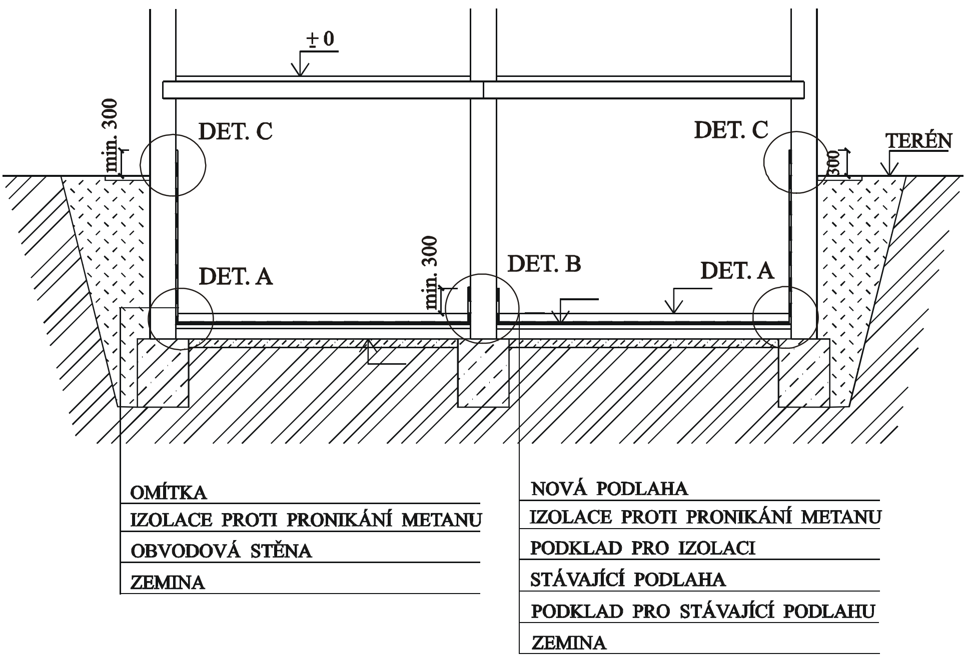

Fig. 5: Principles of the additionally installed insulation which prevents methane from leaking from bedrock in a building with a basement but without water protection

If there is water insulation in the building, a polymer foil is suitable. If the methane diffusion coefficient, D_m, is not known, a sample should be taken in a suitable place (for instance, in the upper part of the vertical water insulation). Then, the sampling point should be properly treated and D_m can be determined on the basis of measurements. If D_m is sufficiently low and the existing thickness of the water insulation is enough to prevent methane diffusion, this water insulation can be used also as a protection against methane diffusion. In that case, only pipes and cable connections need to be gas proof. This could save major costs which would be needed for a new layer of the methane protection insulation. In those cases, a good solutions seems to be the water insulation foils made from High Density Poly Ethylene (HDPE).

When proposing methane protection measures, it is necessary to pay attention to hollow beams in the contact floor (incl. inspection manholes of the inside sewage pipes or water metering shafts). The reason is to prevent accumulation of methane.

The same applies to demolition of buildings. In places where buildings were demolished, it is necessary to check whether there are not any original foundations of the building or under underground structures (such as a cesspool, a septic tank, inspection shaft, vertical sewage pipes or drainage piping) where methane could be accumulating.

4. 2 Modifications in the contact floor ventilation

Ventilation in the contact floor should be modified in such a way so that the methane would not accumulate in one room and so that its concentration would not increase.

This, however, does not prevent methane from penetrating into the building. This method is, thus, suitable only for the buildings which are located in places with very low concentration of methane in soil air ($v_l \leq 10$ %). It is also essential that all structure that touch the subsoil (such as the floor and external walls) should be compact (see the tightness category No. 3 pursuant to ČSN 73 0601 [8]) and that all holes/passages should be sealed (see the Chapter 2. 2. 1 above). This method can be used in the buildings where additional methane protection would be too expensive.

It is also possible to take those measures in the contact floors where people do not stay (such as in basements...). The reason is not to deteriorate heat comfort because of cold air flow in winter. In addition to this, permanent circulation of air would increase heat losses because it would be necessary to heat the space to temperatures set forth in ČSN 73 0540-2 [2] (for instance, t_i = 20 °C), and such temperatures would be considerably higher than the operation temperature (such as t_i = 5 °C). In is also necessary to install sufficient heat insulation of ceilings in the contact floor. It will be cheaper then to modify the ventilation of the contact floor than to install additional insulation against methane penetrating from the subsoil.

5 OTHER PREVENTIVE ACTIONS

Since the existing buildings are generally connected to the public sewage system that is located on the territories where the soil methane is presen**t, it is always essential to check whether the methane does not penetrate into the building through the public and internal sewage system** (it is necessary to carry out a gas tightness test of the internal sewage system pursuant to ČSN 73 6760).

It is also necessary **to carry out a visual inspection whether all horizontal waste pipes are ventilated correctly over the external surface of the roof.** The ventilation heads at the ends of the vertical waste pipes over the roof must perform reliably and must ensure that the internal sewage system will be correctly ventilated. The ventilation heads of the internal sewage system must be in such a height above the level of the roof so that any manipulation with an open fire there (for instance, a repair of the roof or tin-smith components in the future) would be excluded. This requirement can be also met by any other method that is in line with the respective safety regulations governing the occupational safety in environments with the mine gas and methane.

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If any of the methods above is used, it is essential to install in the contact floor of the existing buildings devices that will record the data about the presence of the mine gas and methane (CH_4) as well as the numbers of the respective sensors.

6 PERFORMANCE OF WORKS AND USE

The project documentation should include safety technology requirements for a specific construction and works to be performed in methane environment.

Once the works are completed and accepted by the users of the building, the users of the building must be warned (and information about the warning should be recorded) against making any building changes that would affect the methane prevention protection or measures aimed at reduction of methane inside the building.

7 ECONOMIC ASPECTS

In case of the new building constructions, the methane insulation will increase the costs slightly only, if compared with costs typical of constructions located on territories where mine gas escapes. In existing buildings, the additional methane insulation results is much more expensive than ventilation of contact floors.

In territories where the mine gas escapes, central degassing measures are carried out in bedrock now—this reduces considerably concentration of soil methane which is, in some places, as low as zero. This contributes, in turn, positively, to proposals of methane protection measures for new buildings as well as for new constructions. It is, in particular, the additional methane protection measures in the existing buildings which may save considerable costs because radical decrease in concentration of soil methane thanks to the degassing actions makes it possible to modify the ventilation of the contact floor only and it is not necessary to install additional methane protection insulation.

This means it is advisable to design the buildings in territories where the degassing measures were taken.

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