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CONTROL OF METHANE ACCESSES FROM COAL SEAMS AT DAY GROUND

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ABSTRACT

For the structural control of gas accesses in built-over and to-be-built-over areas the expected gas volume current is to be estimated during the planning and dimensioning of gas drainage systems. In order to make a substantiated statement with regard to the quantity of this gas volume, the source term will be introduced as a forecast model which can be consulted for the calculation of the currently expected gas volume. The source term is a basis for the planning in order to secure buildings, adjacent areas, traffic areas and line marked-out routes against methane spreading and methane accesses. It can be determined on the basis of the geology and the knowledge about mining activities.

In order to minimise the exposure resulting from gas emissions, safeguarding measures have to be initiated in areas with existing and possible gas emissions; normally areas with subsurface coal mining. The status quo of the technological development requires drainage systems of mineral building materials in case of:

- safeguarding measures to prevent methane accesses in the area of buildings and adjacent areas
- prevention of gas spreading in the area of highways and line routes.

At this point geotextiles respectively geomembranes as an alternative to the present procedure for the structural control of methane leavings at the surface and the demands to this alternative building materials will be described.

Key words: methane, source term, geosynthetics, gas drainage systems.

SOURCE TERM

The source term is defined as a measure for the spreading of the methane releases from the source rock into the country rock and describes the maximum gas quantity, which can theoretically migrate to the earth's surface. By considering the source term, a distinction has to be made between the geological (natural) and the anthropogenic overprinted source term. The source term is expressed in $[m^3/(m^2 *a)]$. In illustration 1-1 the confrontation of the different source terms is presented.

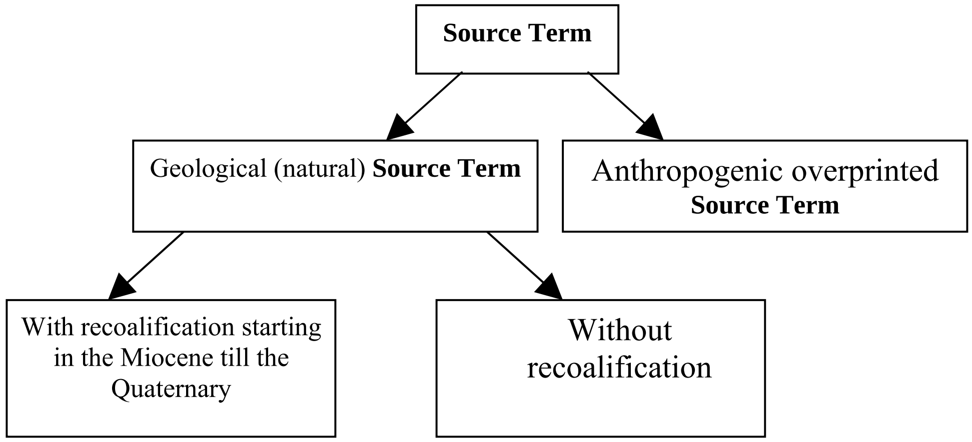

Illustration 1-1.: Confrontation of the different types of Source Terms.

GEOLOGICAL (NATURAL) SOURCE TERM (ACCORDING TO KUNZ, 1994)

Due to the intensive mining activity in the Ruhr district and the resulting loosening rock mass, the geological source term is only very restricted or no longer determinable.

Calculation Basis of the geological (natural) Source Term

The following parameters must be known or be fixed to the quantitative estimate of the gas emission in the maiden formation:

- plain (A): the plain of the examination area
- total coal thickness (MK): taken from geological card plant, mine map etc.
- tectonic factor (F_T) (BENNER, 1998) variable (auxiliary) parameter which writes the projection of the slope cutting surface of a coal seam on the day ground. It depends on convolution and storing of the coal transferring layers (Tab. 2-1)
- coal density (ρ_K): 1,3 t/m³
- methane quantity (q_{CH4}) formed because of the carbonization
- residual gas content (q^t_{CH4}): gas content of coal before mining
- time (t): international used order for the continuance of geologic periods

Tab. 2-1.: Illustration of the dependency of the tectonically factor on the ongoing geology (according to BENNER 1998)

Geology	Tectonic factor
Horizontal seam	1
With 45° dipping seam	1,4
Overlap	2

Calculation of the geological (natural) Source Term

The gas emission abates exponentially and can be mathematically described as follows:

$$V(t) = V(0) \cdot e^{-k \cdot t}$$ equation 2-1

With:
V(t): methane volume at time t in [m³]
V(0): methane volume at the end of the gas formation or at the beginning of the gas emission in [m³]
k: gas emission constant [a^{-1}]
t: time [a]

First the constant k has to be calculated. Dissolving the equation 2-1 after k delivers:

$$k = \frac{-\ln \frac{V(t)}{V(0)}}{t}$$ equation 2-2

The volume of gas emission is V(0) at the end of the gas formation or at the beginning of the gas emission at the time of t = 0. V(0) is therefore the product from the following factors:

- plain A [m²]
- tectonic factor F_T (BENNER, 1998)
- total coal thickness M_k [m]
- density ρ_K [t/m³]
- methane volume ever ton of coal after termination of gas formation q_{CH4} [m³/t]

The outcome of this is:

$$V(0)_n = A \cdot F_T \cdot M_k \cdot \rho_K \cdot q_{CH_4}$$ equation 2-3

Coal is calculated shortly before the mining with $q^t_{CH4.}$ In analogy to this V(t) with the methane volume per ton:

$$V(t)_n = A \cdot F_T \cdot M_K \cdot \rho_K \cdot q^t{}_{CH_4}$$ equation 2-4

The gas emission volume per annum and area is defined by using the difference from V(t) and V(t +1):

$$\Delta V = V(t) - V(t+1) \Leftrightarrow V(0) \cdot e^{-k \cdot t} - V(0) \cdot e^{-k \cdot (t+1)}$$ equation 2-5

The gas emission constant determined in equation 2-2 is used. For t the value of $3*10^8$ years is used, which corresponds with the period since the time of the main coalification till immediate before the beginning of mining.

In the case of consideration of the recoalification during the Miocene the calculation is analogously carried out except for the ascertainment of the parameter $V_N(0)$. $V_N(0)$ is the summation of the CH_4 volume which was formed during the main coalification [V (2.9*10^8 a)] and CH_4 volume which was formed during recoalification [$V_{NEW}(0)$].

$$V_N(0) = V(t) + V_{NEW}(0)$$ equation 2-6

With:
t = 2.9·10^8 a

The methane (q_{NCH4}) formed during the recoalification can exemplarily be taken with 20 m³/t. The newly formed gas volume results as follows:

$$V_{NEU}(0) = A \cdot F_T \cdot M_K \cdot \rho_K \cdot q^N{}_{CH_4}$$ equation 2-7

ANTHROPOGENIC OVERPRINTED SOURCE TERM (ACCORDING TO BENNER, 1998)

The geological Source Term is overprinted by coal-mining in large parts of the Ruhr district. During the coal mining a bulking of the gas leading ground occurred with the conclusion of a changing ground pressure. The previously under influence of the ground pressure at the coal adsorbed methane desorbs and migrates in the direction of the surface.

The transportation of the gas is carried out via different ways. During the active phase of mining the gas exclusively migrates across the air current, the gas extraction and the mined coal in the direction of surface. If the mining is finished, the transportation of the methane takes place more and more over thrown off shafts as well as over the basement and the cap rock.

The volume of the gas emission in the anthropogenic overprinted area depends essentially on the following factors:

- the ground distressing because of mining and out of this resulting decrease of gas pressure
- the residual gas contents of the coal
- seam thickness
- barometric pressure fall
- coal capacity
- the kind of back fill
- reduction ratio of coal

Calculation Basis of the anthropogenic overprinted Source Term

To be able to carry out a calculation of the anthropogenic overprinted Source Term similar to the calculation of the geologic Source Term, the following parameters must be confessed or defined:

- area A of the examination area (m²)
- coal density ρ_K (1,3 t/m³)
- total coal thickness $M_{K,\,aü}$ within the anthropogenic overprinting (m)
- tectonic factor F_T (after BENNER 1998)
- degree of mining activities D, which is taken from mine maps
- residual gas volume before mining q^t_{CH4} (m³)
- current residual gas volume q^a_{CH4} (m³)
- time t (a)

Calculation of the anthropogenic overprinted Source Term

The basis of the anthropogenic overprinted Source Term is analogous to the geological Source Term an exponentially subsiding function:

$$V(t) = V(0) \cdot e^{-k \cdot t}$$ equation 3-1

With:

V(t): methane volume at time t in [m³]

V(0): methane volume at the end of gas formation respectively at beginning of gas emission [m³]

k: gas emission constant [a^{-1}]

t: time [a]

The gas emission constant is calculated analogously to equation 2-2 for the geological source term:

$$k = \frac{-\ln \frac{V(t)}{V(0)}}{t}$$ equation 3-2

V(0) is the volume of gas leaching at the beginning of the coal extraction. V(0) is therefore the product from the following factors:

- area A [m²]
- tectonic factor F_T
- total coal thickness M_k [m]
- coal density ρ_K [t/m³]
- methane volume per ton coal after completion of gas formation q^t_{CH4} [m³/t]
- degree of mining activities D

Thus the outcome is:

$$V(0)_a = A \cdot F_T \cdot M_k \cdot \rho_K \cdot q^t{}_{CH_4} \cdot D$$ equation 3-3

V(t) is calculated analogously to V(0). The only difference is that the CH_4 volume per ton $q^a{}_{CH4}$ is related to the present point of time. It is valid:

$$V(t)_a = A \cdot F_T \cdot M_K \cdot D \cdot \rho_K \cdot q^a{}_{CH_4}$$ equation 3-4

The annual leakage of gas arises from the difference between V(t) and V(t +1):

$$\Delta V = V(t) - V(t+1) \Leftrightarrow V(0) \cdot e^{-k \cdot t} - V(0) \cdot e^{-k(t+1)}$$ equation 3-5

GEOSYNTHETICS

Geosynthetics are products at which at least one component was established from synthetic or natural Polymer in form of an area arrangement, a stripe or a three-dimensional structure. These products are used at geotechnical and other applications in the building and construction industry in the contact with the soil and/or other building materials or medias.

Geosynthetics can be differentiated according to their water permeability or water impermeable (ill.: 4-1). Geotextiles or geotextil related products are permeable to water. Against this geomembranes or geomembrane related products have to be described as impervious to water or almost impermeable.

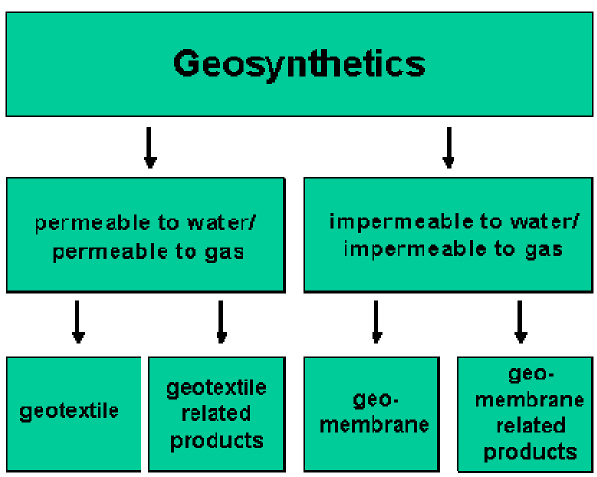

Illustration 4-1.: Division of geosynthetics (differented after SAATHOFF, F. & ZITSCHER, F-F 2001).

Usability of Geosynthetics

Geotextiles as Gas Drainage

Geotextile drainage systems are offered as individual or combined elements. Combined elements consist of a seeping layer and at least a filter layer. As gas drainage a three-layered composite substance is suitable in the area of buildings, plains, traffic areas and line marked-out routes adjacent to it. This consists of a waved labyrinth-like extruded monofilament polymer drainage core (Abb. 4-2), which is connected with a mechanically fixed fleece fabric on both sides (Abb. 4-3). Secudrän WD/gas, a product of NAUE Fasertechnik GmbH & Co. KG is such a gas drainage system. This product is at present in a test stage.

Illustration 4-2.: Drainage core of Secudrän® WD/GAS (WD801) (NAUE FASERTECHNIK GmbH & Co. KG 2003).
Illustration 4-3.: Secutex® geotextile long-term filter (NAUE FASERTECHNIK GmbH & Co. KG 2003).

The medium methane will be carried through the drainage core out without pressure loss. The fleece bandaged with the drainage core holds soil components back while the flow of the gas is made possible vertically to the filter level. The filter therefore serves the function to protect the drainage core against the entry of fine material Entering fine material reduces the diversion capacity of the drainage core. The assembled drainage system is represented in illustration 4-4.

Geomembranes as Gas Barrier

Geomembranes (KDB) are already for many years used as barrier against liquids and gasses. Geomembranes come to the application particularly from Polyethylen of high density (PE-high-density) with BAM admittance and thicknesses of at least 2.5 mm. The KDB Carbofol out of the NAUE Fasertechnik GmbH & Co. KG is usable as a gas barrier.

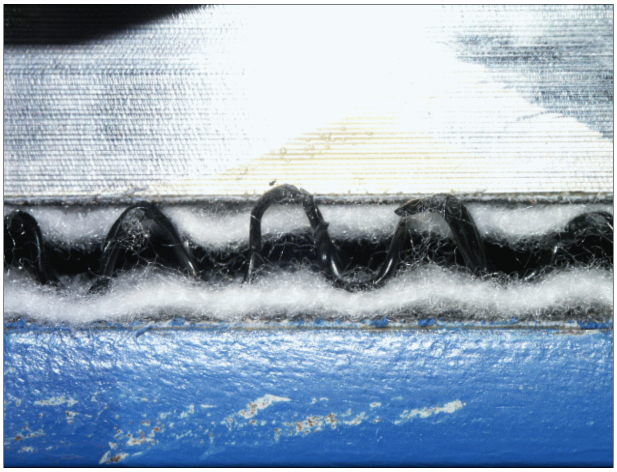

Illustration 4-4.: Secudrän® WD gas drainage system (NAUE FASERTECHNIK GmbH & Co. KG 2002).

Requirements of Geotextiles and Geomembranes

Requirements of Geotextiles (as Gas Drainage)

Drainage materials below a building, adjacent fastened areas, traffic areas and in the area of line marked-out routes must meet certain requirements.

It has to keep its structure as well as the diversion capacity at surchage or at certain traffic burdens, too. Because of that the completely and safely drain of the medium is secured. If a gas shall be drained - such as methane - the used materials must be resistant to this chemical influence.

Additionally, the requirements

- filter stability,
- diversion capacity according to the volume current at surcharge or traffic burden to be expected,
- resistance against chemical and biological influences must be fulfilled according to the factor time.

Previous examinations of NAUE Fasertechnik GmbH & Co. KG prove that high-quality products have fulfilled their function without measurable, significant changes over decades.

To make sure that the geotextile drainage has a sufficient capacity for the current expected gas volume, the new Secudrän product has to be sufficient dimensioned. The dimension foundation for the minimum thickness of the geotextile drainage is the source term.

In analogy to the calculation of the necessary stoutness of a mineral gas drainage the minimum stoutness of the geotextile gas drainage is calculated. The gas quantity which will be lead away is therefore calculated as follows:

$$q_{ist} = Q \cdot l \cdot \frac{b}{2} \qquad \text{equation 4-1}$$

Meaning:

q_{ist} gas quantity to be led away [m³/s]
Q anthropogenic overprinted Source term [m³/m² •s]
l larger edge length of the building [m]
b shorter edge length of the building [m]

The gas quantity which the gas drainage is able to deal with is therefore calculated as follows:

$$q_{soll} = \frac{d \cdot k_f \cdot p \cdot f}{b/2} \qquad \text{equation 4-2}$$

Meaning it:

q_{soll} manageable gas quantity [m³/s]
d thickness of the gas drainage [m]
k_f permeability factor of the gas drainage [m/s]
p gas pressure [Pa]
f Factor of which the gas permeability is greater than the water permeability (empirical investigated factor)

The capacity of the geotextile drainage must be larger than the gas quantity to be lead away. This security factor η is calculated as follows

$$\eta = \frac{q_{soll}}{q_{ist}} \qquad \text{equation 4-3}$$

After inserting equation 4-1 and equation 4-2 into equation 4-3 and solution after d, the outcome is:

$$d = \frac{\eta \cdot Q \cdot b^2}{4 \cdot k_f \cdot p \cdot f} \qquad \text{equation 4-4}$$

To carry out a first calculation of the thickness of gas drainage, the following identification values can be accepted:

$Q = 40\ m^3/m^2 \cdot a = 1{,}27 \cdot 10^{-6}\ m^3/m^2 \cdot s$
$k_f = 2 \cdot 10^{-0}$ m/s (value of an already used drainage core under 50 kPa)
p = 0,01 m (middle pressure difference)
f = 70 (empirical investigated factor)

When putting these values into 4-4 gives up:

$$d = 2{,}26786 \cdot 10^{-7} \cdot \eta \cdot b^2 \quad \text{equation 4-5}$$

If the following values are now used in this equation:
η = 100
b = 15 m

The minimum thickness of the drainage-mat arises (under surcharge):

$$d = 2{,}26786 \cdot 10^{-7} \cdot \eta \cdot b^2 \quad [m] = 2{,}26786 \cdot 10^{-7} \cdot 100 \cdot 15^2 = 5{,}102 \cdot 10^{-3} [m] \quad \text{equation 4-6}$$

In the following illustration 4-5 the edge length of the buildings against the necessary layer thickness of the gas drainage system related to the following security standards is shown:

η = 100
η = 250
η = 500
η = 1000

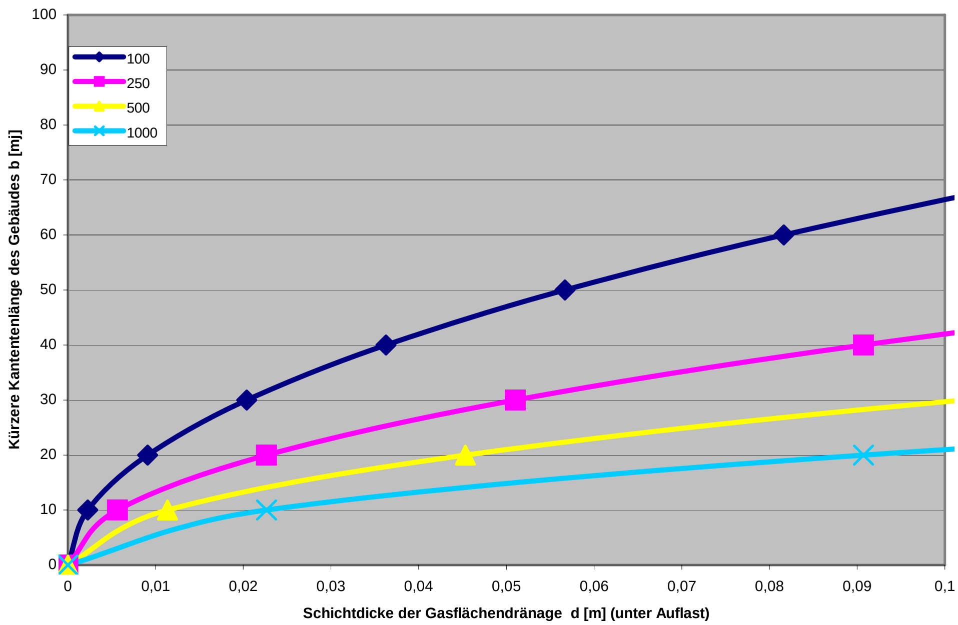

Illustration 4-5.: Layer thickness of the gas drainage depend on building size (under current surcharge).

For the new product Secudrän WD/gas the long-term behaviour has to be checked regarding the form resistance under surcharge.

For the rule (rectangular building with a shorter edge length (maximum 60 m)) the security factor η = 100 is sufficient. In present cases the security factor is insufficient:

- outcrop zone – current stuffed with air – former rock aquifer of the Cretaceous
- overlap, down throw fault, lateral fault

- near to surface mining
- sectors of mining-shafts – within a radius of at least 25 km - (in particular case even much bigger distances can be necessary)

For plains in which there are such conditions the safety standard of η = 100 is no longer sufficiently. Thereby safety standards of far over η = 1000 can be necessary.

Requirements to Geomembranes (as Gas Barrier)

If a geomembrane is used as barrier, it has to fulfil the following qualities:

- resistance opposite the medium
- impermeability (technically thick)
- good processibility

Carbofol geomembranes consist of Polyethylen of high density (PE-high-density).
They are available in different strengths and differently marked structures. PE-high-density geomembranes are technically impermeable opposite methane. Carbofol can be prefabricated well in line marked-out routes for use as a gas barrier. Since mains usually of standard sizes have for the drainage or cable, the parts can already be prefabricated in the work for these. To make sure that no gas can migrate between pipe outer wall and Carbofol, these areas must be sealed up with a methane constant sealing material

RESUME

If the demonstrated geotextiles and geomembranes fulfil the necessary requirements, they can be considered as a resource-saving alternative in contrast to the presently used mineral construction materials in order to secure against methane access and methane transportation.

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