

Josef ALDORF¹, Eva HRUBEŠOVÁ²**RELIABILITY ASSESSMENT METHODOLOGY FOR THE SHAFT DISPOSAL
USING UNPAVED BACKFILL****METODIKA POSUZOVÁNÍ SPOLEHLIVOSTI LIKVIDACE JAM NEZPEVNĚNÝM ZÁSYPEM****Abstract**

In this paper, the authors present reliability problem of the shaft disposal using unpaved backfill, risk factors of this disposal, possibility of eliminating this risk and requirements for the disposal in terms of reliability of backfill stability. Part of the paper are also graphs illustrating the development of the horizontal stress in the shaft backfill, length of the self-stabilization plug and backfill settlement dependence on selected input parameters.

Keywords

Shaft, unpaved backfill, disposal, self-stabilization plug, reliability

Abstrakt

V příspěvku se autoři zabývají problematikou spolehlivosti likvidace jam nezpevněným zásypem, rizikovými faktory této likvidace, možnostmi jejich eliminace a požadavky na obsah projektu likvidace z hlediska spolehlivosti stability zásypu. Součástí příspěvku jsou rovněž grafy ilustrující vývoj horizontálních napětí v zásypu jámy, délky autostabilizační zátky a závislost sedání zásypu na vybraných určujících vstupních parametrech.

Klíčová slova

Jáma, nezpevněný zásyp, likvidace, autostabilizační zátky, spolehlivost

1 INTRODUCTION

The issue of backfill stability in a wider context of reliability of the shaft disposal is a term, the contents of which is vaguely defined in implicitly illustrated requirements of the Decree of the Czech Bureau of Mines (ČBÚ) No. 52/1997 Coll. The Decree does not specify this term either depending on particular conditions of the shaft to be disposed or depending on selected technical and technological solutions.

Therefore, the backfill stability is a term with wide contents and coverage, indicating a comprehensive requirement for shaft disposal reliability. These requirements for backfill reliability when the unpaved backfill is used, these requirements for backfill reliability can be defined in general features:

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1) Minimization of backfill subsidence (compacting) in light of:

- Influence of the backfill material properties compaction, granularity, compressibility, contents of clayish and decomposable admixtures, structural stability, etc.);
- Influence of techniques how the backfill is carried out (amount of the material to be buried, the form of transport into the shaft, implementation of backfilling into a dry shaft, into a flooded shaft, etc.);
- Influence of technical preparation of the shaft for implementation of backfilling (disposal of lining in the shaft, removal of obstacles (footways, dividers, shaft guides, cables, piping));
- Influence of hydrogeological conditions in the shaft in the disposal period and their development after completion of disposal (flooding or drainage of the mining field, etc.);
- Influence of methods for disposal of levels, pit bottoms and intersections of working into the shaft (building of closing barriers, selecting their construction, long-time functionality and reliability, disposal of intersections without closing barriers, etc.);
- Method for checking the quality of capacities to be backfilled.

2) Facilitation of implementation of methods leading to prompt elimination of consequences of increased subsidence of the backfill (subsidence monitoring, construction of a pithead plug making it possible to refill the backfill)

3) Securing the stability of the shaft collar and elimination of formation of depressions in the surrounding of the shaft collar in light of:

- Construction and length of the closing pit bank plug;
- Influence of hydrogeological conditions in the surrounding of the shaft collar;
- Stability of the pit bank plug;
- Method of disposal of shaft channels and workings under the pit bank;
- Implementation of the closing pit bank deck and its carrying capacity;
- Essential dimensions and shape of the safety zone round the shaft.

4) The state of the shaft's stability in the period prior to the commencement of its disposal:

- Impairment and deformation of the shaft lining and predisposition to caving;
- Structural stability of the unreinforced shaft;
- Shaft flooding and need for implementation of backfilling "into the water";
- Shaft collar stability.

The above mentioned factors determine the reliability of disposal and they must be taken into account, monitored and checked in its project and also during the execution of the operations in particular. The outlines for design and assessment of the long-tome reliability of the shaft disposal while using unconsolidated material of gradual granularity of approx. 50-250 mm must respect its resultant structure, which after partial degradation of the grains caused by falls and impacts of the falling material onto the obstacles in the shaft (dividers, carrier beams), reaches virtually its final granularity of 0-250 mm with a minimum of gaps in the resultant backfill buried. This circumstance leads to a different type of behaviour of the backfill in the shaft, particularly in locations of intersections of horizontal workings characterized by "driving" the backfill into the horizontal workings and to formation of the so-called self-stabilizing plugs (Fig. 2) in these workings. This different behaviour in comparison with the backfill using the so-called stone bed on the abandoned levels does not either strictly require to take measures for protection of the external slope of the forced backfill (barriers made of fly-ash and other materials having sufficient carrying capacities).

The difference in mechanical behaviour of the "stone bed" (Fig. 1) results from its high structural compactness achieved by material selection (good-quality stone with the lumpiness of 200-300 mm) and the geometry of the backfill in the shaft.

The conception of secured and forced backfill is an option of disposal with comparable reliability that does not require stone backfills in places of intersections.

2 RISKS DETERMINING THE RELIABILITY OF DISPOSAL

With regard to the existing condition of the shaft and technology of its disposal, it is necessary to define risks in the project that determine the reliability of disposal and create states of threat in the neighbourhood of the shaft in the long term. The principal ones are as follows:

- The way how the material is placed and the optimum granularity of the backfilling material (including the necessity to throw it into water);
- The stability of the backfill in the shaft in relation to the potency of the backfill to get into the area of shaft bottoms, settlement of the backfill, formation of hollows and failure to fill in the space of the shaft;
- Formation of a spontaneous plug in the shaft;
- Excessive subsidence of the backfill due to enormous compressibility of the backfilling material (including the backfill carried out "into water");
- Instability of the shaft collar and threat to the shaft surroundings by formation of a depression.

The risks that are bound to application of the unpaved backfilling material can be defined in the following principal points:

- Instability of the backfill caused by transcendence of closing walls of the stratum intersections, shaft bottoms, etc. that might lead to the occurrence of additional depressions of the backfill in the shaft due to "impression" of the backfill into horizontal workings; the cause of formation of this type of instability is usually the incidence of hydrodynamic forces from water flow;
- Instability of the backfill caused by the occurrence of unfilled spaces in the shaft (formation of spontaneous plugs, unfilled spaces in the footway, etc.),
- Instability of the backfill caused by transcendence of carrying capacity of the closing brick walls in intersections and shaft bottoms;
- Instability of the backfill given by high values of backfill settlement due to high compressibility, presence of hollows in the backfill and areas of low consolidation, formation of hydrodynamic forces in the backfill, etc.;
- Instability of the backfill due to reduction (degradation) of mechanical properties of the backfilling material (at high contents of clayish admixtures and aquifer saturation of the backfill); reduction of strength properties of the backfill would lead to the increase in the horizontal pressure on the closing barrier and wall, to lengthening of self-stabilizing plugs in shaft bottoms and as a result of the consequences, to enhancement of depressions of the backfill in the shaft;
- Instability of the backfill rising due to instability of self-stabilizing plugs in horizontal workings (shaft bottoms); instability of these plugs is determined both by degradation of strength properties of the backfill and action of the hydrodynamic forces at the absence of reinforcing dams;
- Instability of the pit bank plug determining the stability of the pit bank and the shaft collar.

The elimination of the above mentioned risks can be ensured as follows:

- By demonstration of the carrying capacity of the closing walls and dams in relation to their expected loading for its least favourable case;
- By using a backfilling material with low contents of clayish admixtures (up to approx. 3% of volume) and of suitable granularity;
- By obligation to adhere to prescribed backfilling technology and its control in terms of requirements of the Decree of ČBÚ No. 52/1997 (par. 4, 6, 7, 16);

- By carefully and consistently performed monitoring of settlement of the backfill under the pit bank plug and carefully performed addition of the material in the spaces formed under the plug;
- By using a coarse-grained material with granularity of 80-250 mm (type of bottoming) for the backfill in the area of intersections and shaft bottoms (with a predominant fraction of 250 mm).

Favourable factors for implementation of disposal are in particular:

- Good geotechnical and geologic conditions in places of intersections of shafts and shaft bottoms and if there are very consistent siltstone and sandstone strata, which ensure high stability of shafts and adjacent horizontal workings, the reliability of disposal is usually high;
- Load-bearing closing dams established in all access workings to the shaft, the localization of which (distance from intersections) and the lengths (bearing capacity) may reliably stabilize the depressed incoherent backfill;
- Low aquifer-saturation of the shaft and contingent drainage of the backfill;
- Reliable shaft collar plug, containing control and refilling pipeline by which means it is possible to refill the backfill in which subsidence might occur.

3 REQUIREMENTS FOR THE CONTENTS OF THE PROJECT IN LIGHT OF BACKFILL STABILITY RELIABILITY

In light of reliability of the backfill stability, the Shaft Disposal project must compulsorily include the following minimum specifications and detections:

- Backfilling material specifications in light of long-time stability of its structure, petrographic composition, granularity, pollution of the material resources, capacity of resources, transport, etc., demonstrations of ecological suitability, declaration of conformity;
- Determination of technology for implementation of backfilling for given conditions of the shaft, method how to check the volumes to be buried, specifications of technical measures for compliance with the defined procedures (mesh size of the grate, backfilling execution rate), specification of requirements for execution of backfilling in case of obstacles in the shaft (footways, etc.);
- Ventilation during the shaft disposal process;
- Determination of physical-mechanical properties of the backfilling material based on tests, professional estimations, analogy, etc.;
- Determination of the stability state of the shaft, methods for closing old intersections;
- Geological profile of the shaft with indication of shaft sections with stability risks;
- Method of securing levels and intersections and construction of proposed level dams, including demonstration of their bearing capacities and their localization;
- Determination of backfill subsidence amounts, including assessment and quantification of the risks in case of deterioration of level barriers and dams, determination of bearing capacity of closing dams;
- Determination of dimensions of self-stabilizing plugs in horizontal workings and assessment of their influence on the amount and behaviour of the backfill subsidence;
- Shaft collar plug designing, determination of material and geometrical parameters, proof of bearing capacity of the shaft collar also for extraordinary loading;
- Method of disposal of near-to-surface workings under the shaft collar;
- Construction, geometry and proof of bearing capacity of the shaft collar deck.

In order to assess principal stability and reliability parameters of disposal, it is necessary to utilize recommended algorithms for their determination, or assessment.

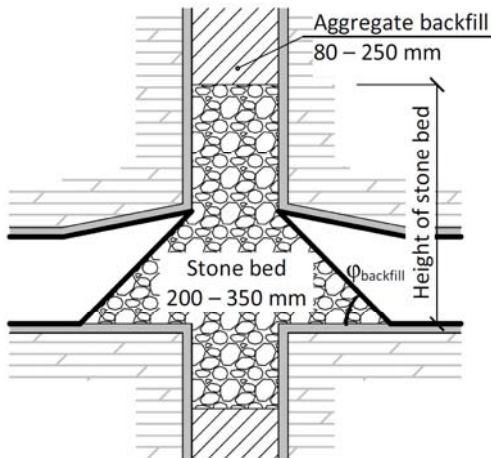


Fig. 1: Stone bed in shaft bottom

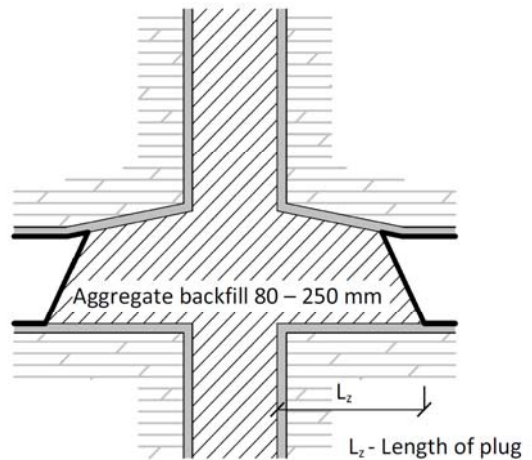


Fig. 2: Self-stabilization plug in shaft bottom

Examples of results of solving basic reliability parameters of disposal are shown in Fig. No. 3-5 for the magnitude of horizontal stresses in the backfill, the length of self-stabilizing level plug (length of the depressed backfill) and backfill subsidence versus the length of shaft to be eliminated. Descriptions of the algorithms used are presented in [1].

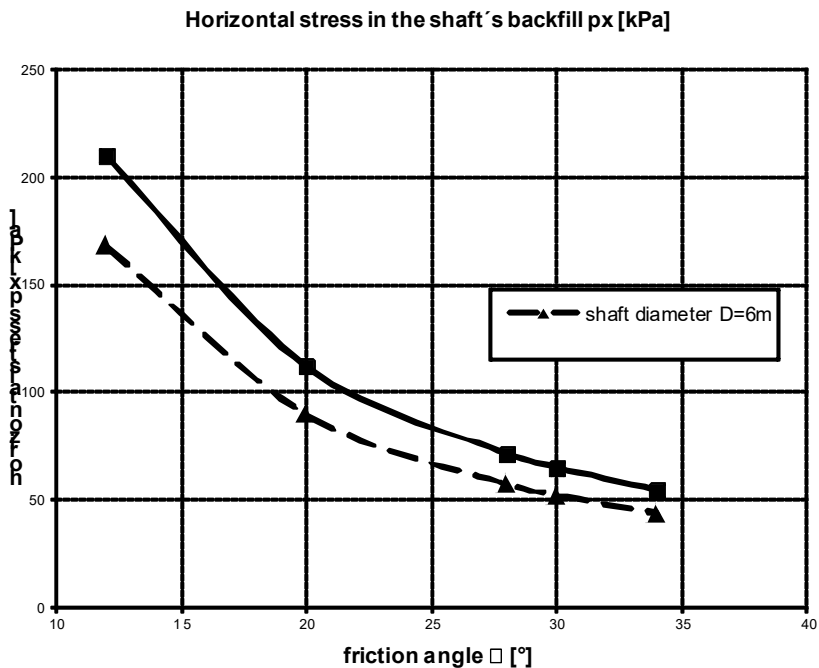


Fig. 3: The chart of horizontal stress in the shaft's backfill versus friction angle

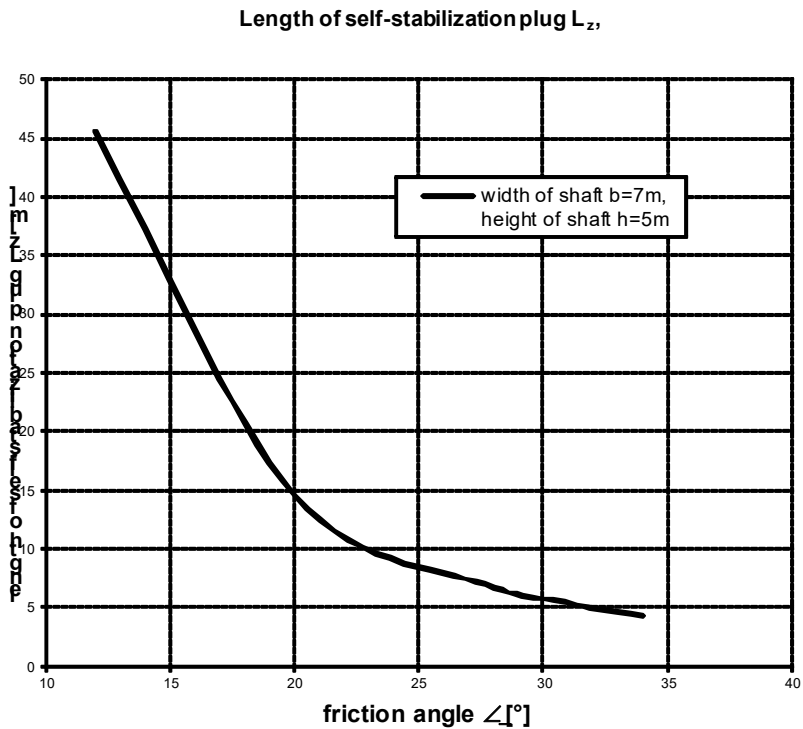


Fig. 4: The chart of self-stabilization plug length versus friction angle

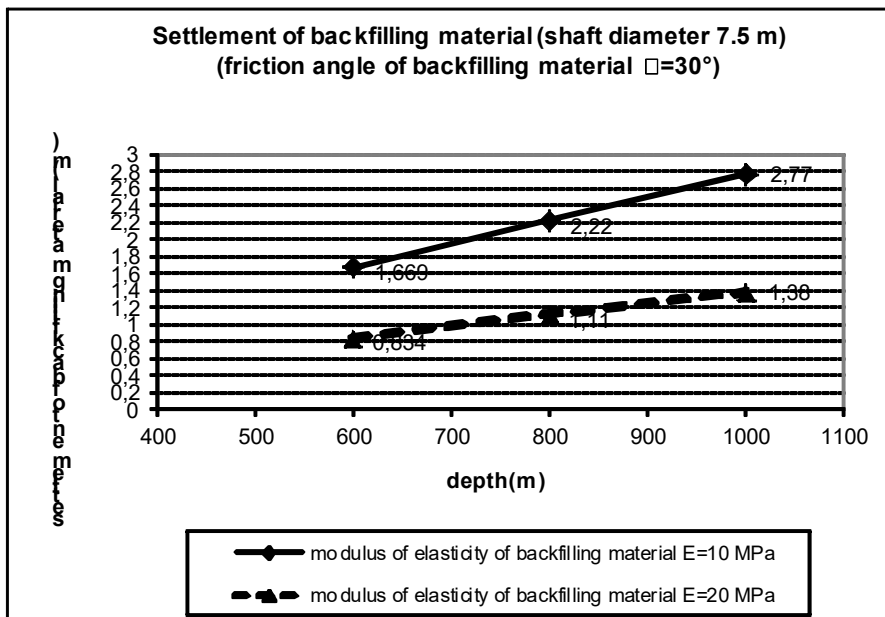


Fig. 5: The chart of backfilling material settlement versus depth

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- [1] ALDORF, J., HRUBEŠOVÁ, E. *Disposal of shafts using incoherent material*. Comprehensive recommendation of the ČBÚ project No. 36-05. Ostrava 2007.

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