Trabajo Final de Grado Arquitectura Técnica

POLAND - Gliwice

modalidad de intercambio académico curso 2014-015

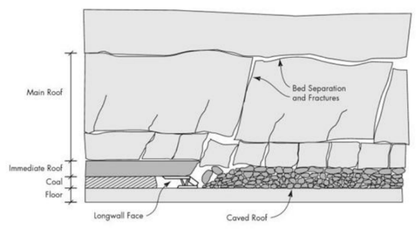
Protection of Buildings in Mining Areas

Underground Mining

- Changes of water conditions
- Rock mass elements displacements
- Rock mass tremors

What is Mining Subsidence?

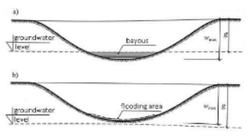
1. Mined area
2. Stress state disturbed
3. Collapse
4. Fractures and settlement
5. Deformations and displacement
6. Mining subsidence



Changes of water conditions

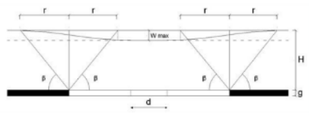
Water drainage occurs when there is not any waterproof layer in the rock mass to provide insulation against the flow of water into the mine.

Floods occurs when in the rock layer are one or more waterproof layers that produce water isolation in the surface or close to the surface.



Continuous deformations

- Most common deformations,
- Slow development,
- Occur over large areas,
- Usually associated to longwall mining method.



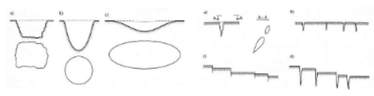
"r": main influence range $r = \frac{H}{tg\beta}$

In the USCB tg β = 2,0

Discontinuous deformations

- Local deformations,
- Sudden development.

- Surface deformations
- Linear deformations



- Sinkholes,
- Landslides,
- Local deformities.

- Ditches,
- Fissures,
- Ground braces.

Mining tremors

- Dynamic phenomena,
- Short duration,
- Violent.

Mining tremors can be:

- Tectonic, unrelated to mining activities,
- Operational, produced by mining activities.

Mainly occur when mining operations are carried out at greater depths.

Mining tremors are characterized by:

- Vibration acceleration, a (t)
- Vibration velocity, v (t)
- Vibration frequency, f
- Duration of vibration, t

Mining impacts on buildings

The behaviour of the building facing the mining impacts depends mainly on the type of the structure.

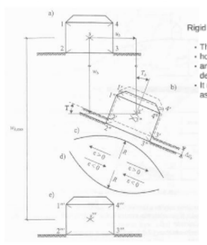
Classification of structures in mining areas:

Classification base	Features of structures (segments)		
shape of structure horizontal projection	compact	linear	surface (extensive)
Structure deformation ability on deforming subsoil	rigid		deformable
Structure functional sensitiveness to mining exploitation impacts	very sensitive	little sensitive	insensitive
Maintaining utilization safety and utilization values	resistant	partly resistant	non-resistant
Range of use	mass		unique

Rigid structures include buildings with walls made of masonry or reinforced concrete, prefabricated elements, as well as frame structures with masonry fulfillment.

Continuous deformations

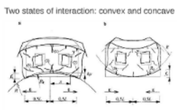
Displacement of a building in the mining basin:



Rigid building:

- The structure is subjected to vertical subsidence (wb)
- horizontal displacement (ub),
- and its geometric center "S" suffers a rotation determined by its tilt from position (Tb).
- It may occur additional sinking, causing the object to assume the position 1' - 2' - 3' - 4'.

Two states of interaction: convex and concave



Discontinuous deformations

Discontinuous deformations may induce the loss of stability of a part or the whole structure.

The lands exposed to the hazard of discontinuous deformations are not recommended for building development.

The most effective protection against the discontinuous deformations consists in eliminate its causes, filling the voids in the rock mass. This method is expensive and sometimes, is not possible to fill the existing voids.

Mining tremors

Mining tremors produce horizontal forces dependent on:

- weight of the structure,
- its geometrical features,
- tremors maximal acceleration.

$H = f(G, a_p, \eta)$

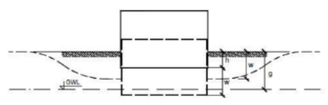
Mining tremors tend to produce cracks on residential buildings.

Impacts caused by mining tremors can be omitted in the analysis, when the value of the vibration acceleration "ap" up to 250 mm/s2 for rigid buildings with a continuous stiffening wall and height up to 11 floors.

Lands exposed to the impacts of continuous deformations falling into categories 0-IV and to the impact of mining tremors with the acceleration up to 1000 m/s2 are suitable for building development.

Changes of water conditions

Changes in the water conditions require proper forecasts. When flooding occurs, a waterproof membrane or proper drainage may be needed. In any case, this may be insufficient in the event that part of the foundation or basement is located below the level of groundwater, when "g" < w + h.



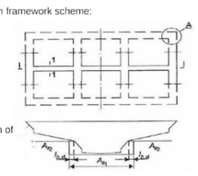
Changes in the level of groundwater can involve the total exclusion of the ground or require preventive solutions, as insulation or additional drainage.

Design of Buildings

Foundation framework

- Absorbs tensile forces and bending moments and their combination.
- Also absorbs internal compression forces.

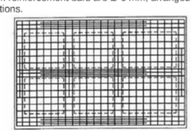
Foundation framework scheme:



Distribution of horizontal forces:

Reinforced concrete slab

- Ensure the stiffness of the foundation and it can be used as a basement floor.
- Thickness of 10 cm
- Is reinforced over its entire surface, in the middle of its thickness, both axis.
- Increase the section of the reinforcement under bearing walls, in the direction parallel to the walls.
- The minimum reinforcement bars are Ø 6 mm, arranged each 25 cm in both directions.

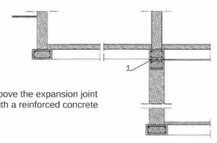


Basement floor

- Monolithic structure
- Floors of reinforced concrete.
- Basement walls can be made of:
  - reinforced concrete
  - precast concrete,
  - masonry (when upper floors are made of masonry)
  - frame structure with masonry fulfillment (up to category II)

Partially different foundation level:

- expansion joint
- sliding layer



Structure located above the expansion joint will be reinforced with a reinforced concrete ring-beam.

Structural walls of floors above ground

Wall structures:
Increase the number of anchors that connects the exterior wall with the inside of the structure:

- 5 anchors/m2, up to second category,
- 6 anchors/m2, above the second category.

Frame structure with masonry fulfillment:
This type of structure is considered rigid when the radius of curvature of the structure Rb is not smaller than the limit radius Rgr:

$$R_{gr} = \frac{L - a}{2000\,\Theta_b} \leq R_b$$

Where:

L – Segment length [m].
a – Distance between columns in extreme fields [m].
Θ_b – Deflection of the structure walls, induced by land surface curvature.
R_b – Radius of curvature of the structure [km].

Reinforced concrete slabs and beams

Reinforced concrete slabs made "in situ" are recommended.
Slabs made of precast elements:

- finished with a layer of concrete of not less than 3 cm thick,
- reinforced in the direction perpendicular to the longitudinal reinforcement of the precast elements.

Slab above the basement need reinforcement arranged perpendicular to its axis. Minimum diameter of reinforcement is 5.5 mm placed every 25 cm and anchored in the beams.

Reinforced concrete beams made "in situ" around the perimeter (ring beams) and along the load-bearing walls.

In buildings made of precast elements is recommended to use ring-beams made in situ to increase the stiffness of the structure.

Minimum reinforcement for beams is 4 bars with a diameter of 12 mm.

Foundation framework

Continuous footings need to be reinforced to withstand tensile forces and horizontal bending moments that occur in the plane of the foundation.

Cross section:

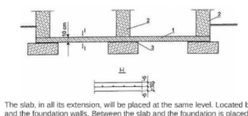
"As": necessary reinforcement positioned along the base and sides of the continuous footings.

"A,m": reinforcements placed on the vertical edges to absorb bending moments.

"ΔAs = As - A,m": remaining reinforcement placed along the base.

method of anchoring in the corners of the continuous footings for the longitudinal reinforcements.

Reinforced concrete slab

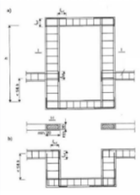


1 – diaphragm;
2 – basement walls;
3 – sliding layer.

The slab, in all its extension, will be placed at the same level. Located between the foundation and the foundation walls. Between the slab and the foundation is placed a sliding layer.

Description of sliding layer	Value of friction coefficient (f)
Two layers of roofing felt (without spacers), normal stresses:	
σ = 0.1 MPa	0.7
σ = 0.15 MPa	0.6
σ = 0.20 MPa	0.5
σ = 0.25 Mpa and more	0.4
Two non-sanding tar board layers with interlayer made of:	
Smoking-box dust	0.4
soot	0.3
Powdered graphite	0.2
Artificial foils with interlayer made of graphite grease:	0.15

Reinforced concrete slabs and beams



In case of making an opening in the slab with a size greater than 6 times the width of the floor (stairwell or elevator shaft), must be placed a concrete beam around the perimeter of the hole to ensure the transfer of horizontal forces.

In the same way, openings in walls must have a reinforcement made of reinforced concrete, around the perimeter or at its bottom.

a) beam height > ¼ h,
b) beam height < ¼h

Modifications of existing buildings

Cutting out a part of the building or removing an entire building from a row of buildings, to provide space for compression.

Install pre-tensioned steel mesh around the exterior walls of the building. It can be dismantled later and re-used.

Provide temporary support or strengthening to parts that may experience damage.

Support partitions and ornaments independently of the walls and floor.

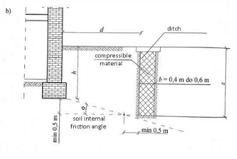
Steel tie rods attached to anchor plates are employed in masonry walls (brick, block, etc.) to carry tensile loads and save the walls from succumbing to lateral forces.

Tie rods are positioned at ceiling levels and increase the overall stiffness of the structure. These are often seen from the outside of the walls as a cross or rotates S shapes. Sometimes the rods pass right through the building; others are embedded into an internal wall.

Abusive use of tie rods may disfigure the building and cause additional cracks.

Reduction of the earth pressure generated by compressive strain in the ground by the construction of a deformation zone.

- Digging trenches around the building.
- Backfilled with compressive material to absorb horizontal strain. (expanded polystyrene foam, vermiculite or cork)
- Placed as near as practical to and reach greater depths than the foundation level.
- Can be covered with concrete slabs.



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