Environmental conservation along Bucharest underground lines

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ABSTRACT : Impact of the metro works with the environment appears as a large action field, which contributes to the soil condition, continuing with the atmosphere and the most important aspect- inhabitants' every day life that lives along the metro route or use the metro. The paper emphasizes the studies of metro designers in order to minimize the negative effects of relation between metro works and environment.

RÉSUMÉ : L'impact des travaux de métro sur l'environnement apparaît comme un grand champ d'action, qui contribue à la condition des sols, se poursuivant avec l'atmosphère et l'aspect le plus important – la vie quotidienne des habitants qui vivent le long de l'itinéraire du métro ou utilisent le métro. La communication souligne les études des créateurs du métro pour réduire au minimum les effets négatifs de relation entre les travaux du métro et l'environnement.

1 GENERAL ASPECTS

Bucharest benefits of about 70 km metro network, which has been operating for 27 years. There are also extensions under construction, 7km which will be finished in 2005. The map from Figure 1 illustrates the underground lines in Bucharest city.
Having the approximately area of a circle with a

diameter of about 22 km. One of the most important problems of the Romanian metro designer's team is reducing at the minimum possible the environment. Impact level on the subway environing generated by the underground structures performing and also by the underground train car traffic. This paper emphasizes a complex issue, relation between metro lines and environment, based on the data obtained from:
- study of the soil behavior when the shields are advancing,
- study accomplished while precincts with diaphragm walls were performing; it has to ensure the excavation stability and waterproofing for the aquifers infiltrations,
- complaints received from the inhabitants who live in areas,
- researching in order to promote new monitoring systems and behavior of the works in time.

2 SITE NATURAL CONDITIONS

Taking into account the geotechnical information resulted from over 2000 geotechnical borings and using the classification made in our technical literature, the following strata have been identified according to the lithological profile presented in Figure 2.

Type 1 stratum: recent surface sediments, made up of vegetal soil and clayey sediments, with a thickness locally reaching 15 m.

Type 2 stratum: Upper Sandy-Clayey Complex, is constituted of loess formations, often moisture

Type 3 stratum: Colentina Gravel Complex, made up gravel and sand (with large variations in grain size) and frequently with water bearing clayey layers, with a variable phreatic level from 1.5 m to 14.00 m. Thickness locally reaches 20 m. The specific average permeability coefficient of these aquifers is between 50 m to 250 m per day.

Type 4 stratum: Intermediate Clay Complex, made up of alternating brown and gray clays, with intercalation of hydrological fine confined sandy layers. The thickness of this layer reaches a 20 m maximum in the North of the city, but towards South it becomes very thin disappears.

Type 5 stratum: Mostistea Sand Complex, a confined water-bearing layer made up of fine gray sands with lenticular intercalation of clay. Its thickness varies from 10 m to 15 m. Sometimes the underground water communicates with the upper unconfined layer, such that the water pressure level is approximately the same as the phreatic level.

Type 6 stratum : Lacustrine Complex is made of clays and silty clays, with small lenticular sandy layers, most frequently situated at the top of this complex.

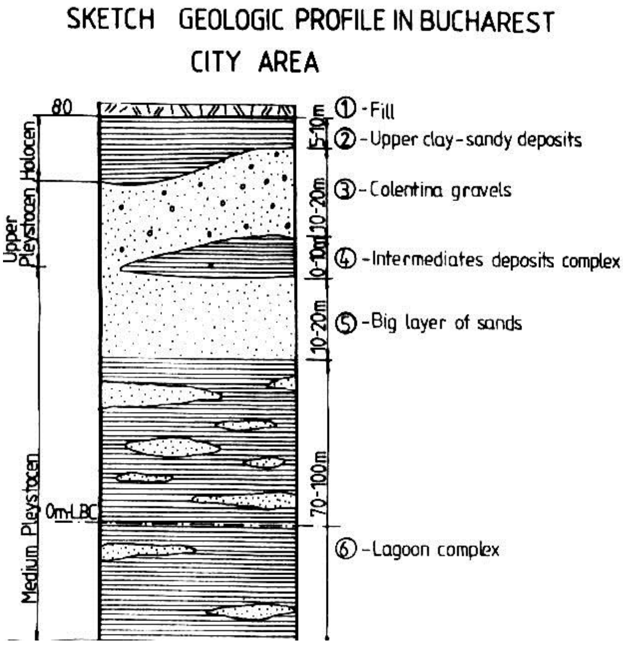

Figure 2.

Type 7 stratum: Fratesti Sand Complex is the deepest bearing stratum, made up of sands and gra-

sensitive, with sand layers and overall thickness of 15 m in the North and less than 1m on the river side.

vel, from which industrial and drinking water is usually pumped out.

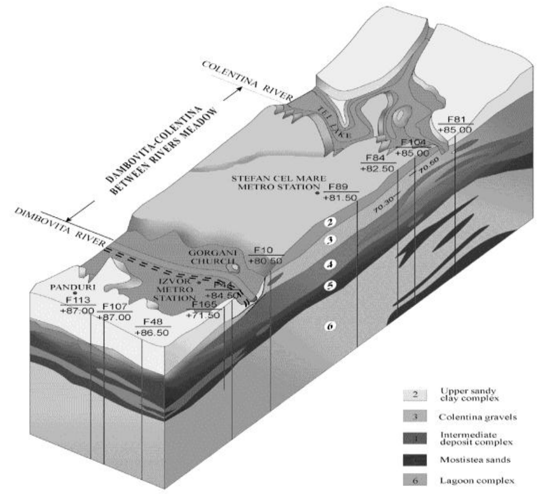

Figure 3.

3 UNDERGROUND WORK TECHNOLOGIES AND TECHNICAL PROBLEMS

The negative impact on the environment is very often justified by the unfavorable site natural conditions, soil nature and higher water level.

As a consequence of the constructive activity of metro works, deterioration processes of the environing soil could appear.

Metro rectangular tunnels and extraction or launching pits are made in open excavation at the surface. For this objective, the excavations are performed in precincts with diaphragms walls using mud as a protection method.

Support elements are designed to perform step by step in the same time with the excavation using horizontal tensioned struts and anchors.

Draining wells are designed in order to ensure necessary conditions for the excavation and structure works. These wells are adapted to the hydrogelogical conditions of the local area.

The existing tunnels were excavated using the semi-mechanized open face shield, with 6.50 m in exterior diameter. Waterproofing technology for these structures is achieved by means of: closing the transversal and longitudinal gaps, special grouting behind the lining, grouting with controlled straightening, grouting for reducing infiltration and finally resin grouting.

Romanian semi-mechanized shield is designed to run in the field with totally or partially open front.

It is well known that this technology has always involved/implied settlements of the ground surface because of the loosing soil as a consequence of digging on the front of shield and creating the outline gap, which remains after the advance of its metallic covering.

From past experience in this field it is known that recent soils, non-homogenous are made of clays and sands that punctually suffer some settlements, followed sometimes by collapse at the surface where there were cumulative and favorable factors.

Suffusion phenomena appear at the bounding joint between the tunnels with the stations that caused punctually alteration of the physical and mechanical characteristics of the environing soil.

The technical accidents caused sometimes when diaphragms walls are performing horizontal displacements, gaps etc. lead to the infiltrations with solid material with water followed by reducing the passive resistance of the environing soils.

4 ENVIRONMENTAL IMPACTS OF THE METRO LINES IN BUCHAREST

Metro underground structures, like any other important underground structure as: public utilities networks (heating and sewerage networks, aqueducts), underground passages, underground parking (sheltered very often on the highest building basements), commercial centers with deep basements; all these are important examples of underground constructions that can cause around them environmental problems.

Pollution emissions affect de environment both during the construction works but also after that. E.g. Fuel necessary for the site traffic and equipments functionality, dust emissions from the concrete stations, noises from the performing technological processes of metro, solid, vegetal and liquid waste (used fuels), waste, sewage sources, etc.

Figure 4.

Figure 5.

The execution technology hasn’t always been correct. The consequences were obvious – technical accidents followed by the modification of hardening state level or the consistence of the soils nearby the tunnel structures (rectangular and circular) followed by the settlements. Some examples were identified along the metro routes (see the photos above) but the remedial answer was in optimal time so that the material loosening wasn’t significant.

The “dam” phenomenon (when the underground structures are perpendicular relative to the underground water streams and the buildings weren’t foreseen with special elements of drainage for sustain the water level) appear after the underground works were finished.

E.g.: Semanatoarea - Piata Unirii metro route, especially Botanical Garden area need special waterproofing works in order to rehabilitate flooded basements.

Noise and vibration emissions are the most important pollutants resulted from the metro activities.

The comforts of the passengers and metro staff and also the inhabitants who live nearby metro routes have imposed a minimum noise and vibration level.

In general, a dynamic structure radiates both noise and vibrations in the same time. Hence, detailed research of the acoustic pollution causes is justified and leads us to the methods necessary in order to reduce/minimize the emissions. E.g. rolling the wheels, working electro motors, ventilation systems and electrical heating equipment for refreshing the air into trains, low power supply equipments etc.

This chapter emphasizes only the issue of acoustic pollution (noise and vibrations) because of the space.

5 SOLUTIONS AND TECHNOLOGIES FOR ENVIRONMENT REHABILITATIONS AROUND AND ALONG BUCHAREST METRO LINES

Relation environment – underground structures promotes various problems, which leads us to design and operate specific rehabilitation technologies and works.

The method for reducing the noise and vibrations intensity level is described below.

For a good determination and characterization of the proposed problem, organizing the guidelines for research has been done by: a) determination the characteristics of vibration and noise underground sources as the main factor for pollution, considering the elements which have important influence on the intensity levels; b) determination the transmissibility characteristics of the ground nearby the tunnels and stations, and establishing an "approximate influence zone" of the metro route; c) measurements for determining vibration and noise intensity levels in buildings placed nearby the metro route and into the tunnels; d) comparing the measured intensity level with admissible level in Romanian norms/legislation; e) determining the influence of each element of rail track system on the measured values and how the modifying of elastic characteristics of these elements can influence the decreasing of intensity levels of noise and vibration; f) identifying the real ways to operate the modifications in improving the elastic properties of the rail track system elements.

E.g. : a) Republica-Pantelimon section of 1st Metro Line.

The measurements have been done in 12 different locations (houses) placed at 4÷6m above tunnels. The initial rail track system was ballast bed track with wooden sleepers. After vibration and noise measurements, it was obviously that the claims were justified: the results were above admissible limits. Therefore, it was taken the decision to improve the elastic characteristics of rail track system.

On the first 200m of section, the solution applied was "reinforced concrete floating slab track" and on rest of section the solution applied was "ballast bed track with under-sleeper pads".

The reinforced concrete floating slab track system consists of: elastic clamps for fixing rail; polyurethane sleepers; rubber cover for sleepers; fiber glass mats between reinforced concrete slabs.

The ballast bed track with under-sleeper pad system consists on: elastic clamps for fixing rail; wooden sleepers; rubber cover for sleepers; elastic under-sleeper pad TIFLEX type.

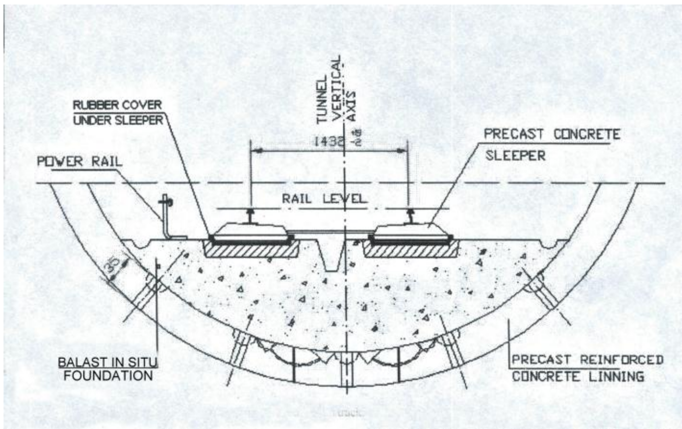

Figure 6. Reinforced concrete sleepers on concrete foundation track

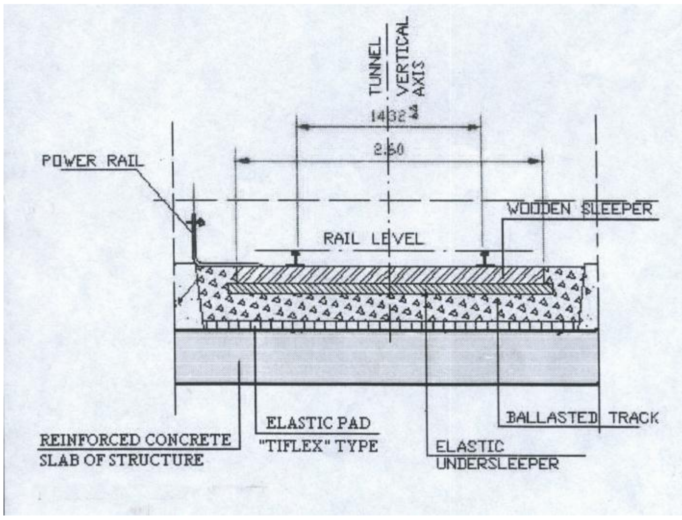

Figure 7. Ballast bed track with elastic pad

b) In tunnels of 1st Metro Line.

For other locations on 1st Metro Line, measurements have been done directly on the rail system track. This type of track consists of reinforce pre-cast concrete sleepers placed directly on the rail foundations and covered with rubber pads. Fixing system for rail was done by elastic clamps K- type and VOSSLOH-type.

c) Locations on 4th Metro Line.

In tunnels, the locations were picked as follows:

- first location: tunnel between Gara de Nord 2 Station and Basarab 2 Station (rectangular shape cross section, cut-and-cover method), rail track on ballast bed, 1cm thick elastic pad under the ballast layer, 2 cm elastic under-sleeper, wooden sleepers, 0,5 cm thick elastic under-rail pad, elastic rail clamps PANDROL type;

- second location: tunnel between Basarab 2 Station and Grivita Station (circular shape, 6,4m in diameter, open-face shield method), pre-cast concrete sleepers, 2cm thick elastic under-sleeper, 0,5cm thick elastic under-rail pad, elastic rail clamps PANDROL-type.
- third location: tunnel before 1 Mai station, rail crossing and switches area (rectangular shape, cut-and-cover method), situation identical as in first location.

Processing data recorder in underground tunnels was done by numerical analysis in a computer program, specially created for this purpose. The methodology was:

-selecting a period of time for recording which should contain at least 10 passes of metro trains;

-uncoupling the passes of metro trains so each recorded file should contain one pass;

- fixing maximum value of acceleration and of RMS ("Route Medium Square" acceleration); for each train pass;
- fixing the average value for 10 train passes;
- representing results in a diagram.

At the ground surface, the building locations were chosen inside the settlements area of the tunnel structure. The locations were selected as follows: 174 Calea Grivitei (first location), 216 Calea Grivitei (second location), and 234 Calea Grivitei (third location).

The measurements contained data recorded at the building basements, concerning car traffic sources and metro traffic source, simultaneously in two different points on three directions: transversal and longitudinal of building axes (parallel and perpendicular to tunnel axis) and vertical. In this manner, the data were recorded on six channels (2 points x 3directions).

For all locations, the longitudinal direction was parallel with tunnel axis and transversal direction was perpendicular on it.

6 CONCLUSIONS

On 1st Metro Line

Applying solutions for reducing noise and vibration intensity levels for rail track systems in Bucharest metro , leaded to a real improvement all these intensity levels decrease under admissible limits .Thus , medium accelerations decreased about 15 – 26 times for minimum values and about 5 – 7 times for maximum values . All frequency spectra for global medium accelerations on spatial directions decreased under admissible limits.

Vibration intensity levels decreased fewer than 10 vibrations, which represents no any danger for buildings and human body, in practice imperceptible.

On 4th Metro Line

In view of results of applying above solutions for decreasing noise and vibration intensity levels at Bucharest metro lines in function, these solutions were applied on rail track system at the new metro line (4th Metro Line, in 3,5km length) put into operation on 1st of March 2000. Thus, in the rail track system were provided elastic elements for vibration dumping between rail elements on the one hand (elastic clamps for rail fixing , rail pads , base plate pads, under-sleeper pads) and between rail track and its foundations on the other hand (ballast mats).

Analyzing the results recorded on this new metro line, the vibration and noise intensity levels decreased more, reaching much and the admissible limits, for structural safety and human comfort.

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