PHOTOGRAMMETRIC MONITORING OF THE STRUCTURAL ELEMENTS OF THE DEFORMATION AT THE RAILWAY TUNNELS USING THE INTERACTIVE PROCESSING SYSTEMS

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ABSTRACT: The actions of the physical and tectonic agents on the railway tunnels have resulted in some deformation of the resistance structure of the structural rings. The work describes the measuring technology of the transverse profile in the tunnels using terrestrial metric chamber and directional actinic beams. Data processing using the interactive calculating systems realizes some numeric and graphic profiles, deformations of the control points, the geometrical elements of the railway axis, free traffic gauge profile and geometrical state of the overhead line for electrification.

The combined action among infiltration, frost-thawing cycle and tectonic vibrations entails the resistance structure deformation of the constructive railway tunnel rings. These deformations will appear as infiltration cracks or displacements of the ogives as against the designed axis. The periodic supervision of these displacement shapes and values is required both by reinforcing specialist and by the railway running administration choosing the routes for the overgauge transport.

To solve all these problems it is necessary to measure periodically at each tunnel, the followings :
- the displacement in time of some premarked points in special sensible zones;
- the inner geometry of the free tunnel ogive;
- the railway axis position as against the tunnel ogive axis.

± 5 mm is the necessary accuracy both for the reinforcing specialist and for the person checking the free passing gauge. This tolerance is generally approved by all European railway administrations.

Measuring Method

Railway axis layout and picket elevation establishment are previously carried out for each tunnel using geometric levelling. The pickets are marked on the railway axis on each constructive ring and in addition in the points where cracks, infiltrations or breakes had appeared (Figure 1). All these points are marked by witness marks.

According to this method, a profile across the tunnel axis just ahead the marked pickets using a very actinic and fine diverging luminous point has been implemented. A special halogen lamp projector, having a maximum 10 mm diameter luminous spot at a 10 m distance, has been developed. Four checking marks

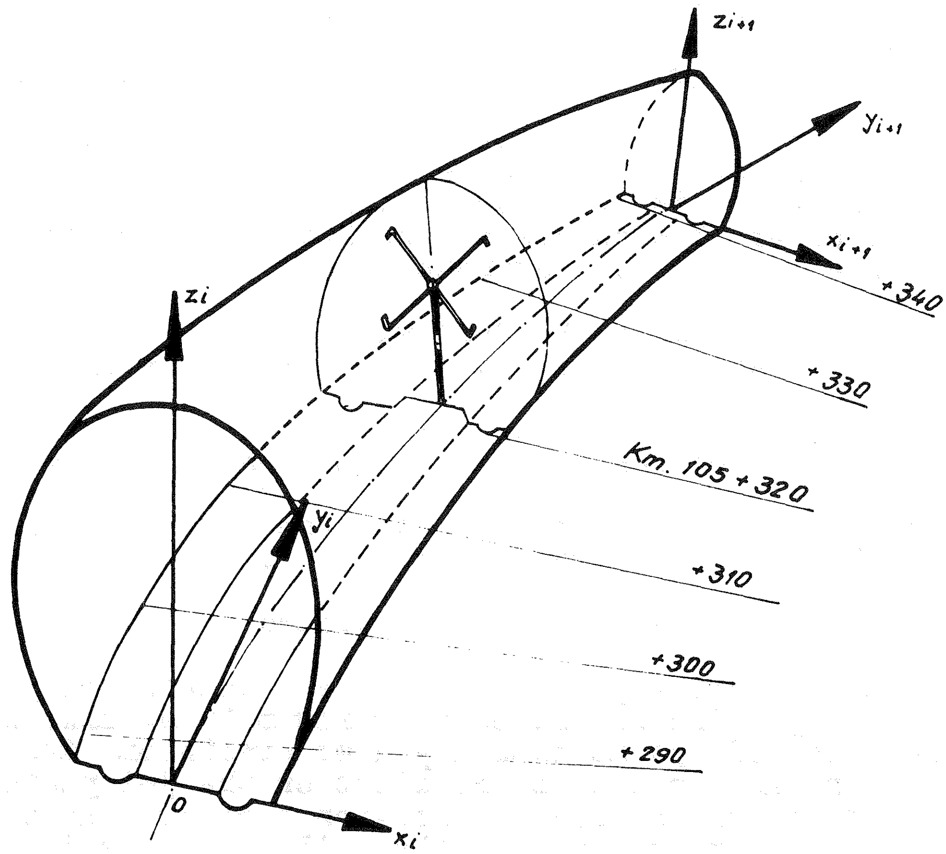


Figure 1 The scheme of the system of coordinates in the tunnel

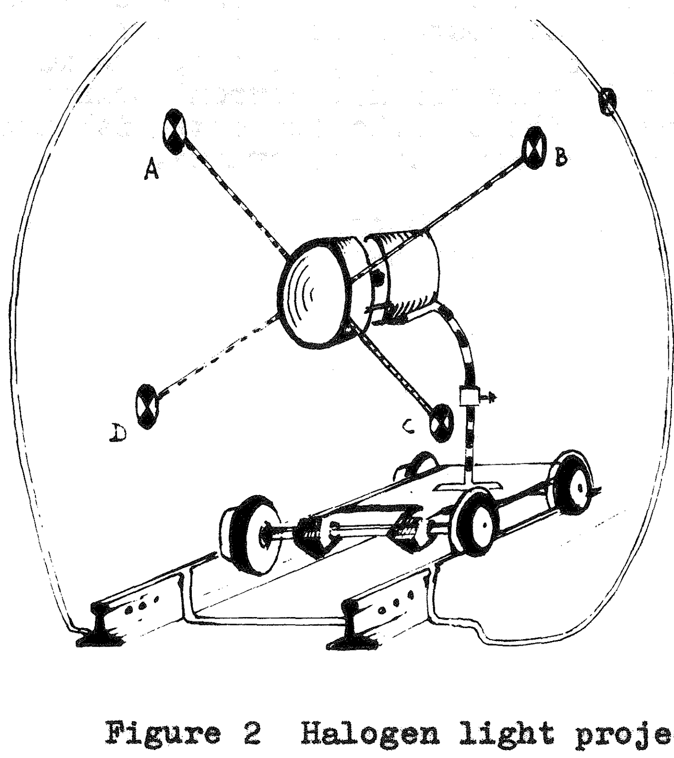


Figure 2 Halogen light projector

placed at the ends of some invar bases and an attachment system allow the luminous spot verticalization with a 10 secconds accuracy and the photograph outer orientation checking (Figure 2). The crossing of the luminous spot with the tunnel inner ogive represents the required transverse profile, which photograph is made using UMK 10/1318 camera having a 100 mm focal length. The photograph is processed using plates with a 23 DIN sensitivity, type WP. The camera is quasiparallel oriented with the profile plan made by the luminous spot.

The processing algorithm is the following:

1. The calibrated camera is placed at 10 m from the first profile i=1
2. The plate j=1 is placed in the camera
3. The consecutive profiles i, i+1, i+2 are photographed on the j plate
4. If the profiles are not finished, the camera is placed at 10 m from the last photographed profile (i+2) and the j+1 plate is loaded
5. i:=i+2. The operations from 3 are repeated

In this way, each photograph includes three consecutive profiles. The third profile is placed at maximum 30 m, allowing to determine a certain point with a $\pm$ 2 mm precision. Every third profile on the j plate is the first on the j+1 plate. On each profile there can be seen the section contour, the four checking marks, the upper level of the rail and the eventual points marking the cracks/deformations in evolution.

Data Processing

Photograph measurements are made using mono- and stereocomparators equipped with coordimeters. There are recorded the inner orientation element coordinates of the photographs, the four checking marks of the A,B,C,D scale, the rail upper-inner level (for axis and track width), current points on the bank, ogive and the key of the profile (to establish the gauge) and the possible checking marks of the cracks.

Photograph coordinates are changed into ground coordinates, using congruent transformations:

$$X = m\left[X' + \cos^2\left(\operatorname{arctg} \frac{X'_A - X'_D}{X'_B - X'_C}\right) \right]$$

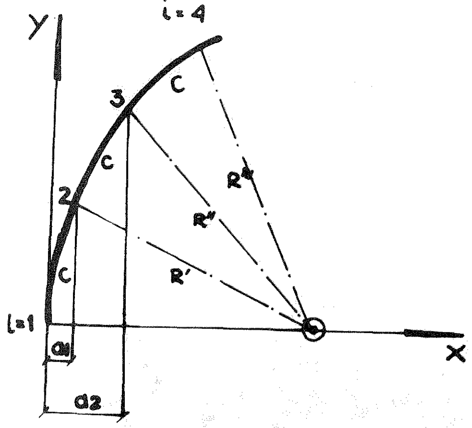
$$Y = Y_{(picket)} - f\left(1 + \frac{X'^2}{f^2}\right) \sin\left(\operatorname{arctg} \frac{X'_A - X'_B}{X'_D - X'_C}\right)$$

$$Z = Z_{(picket)} + mZ'$$

$$m = \frac{1}{2f}\left(\frac{A-C}{X'_A - X'_C} + \frac{B-D}{X'_B - X'_D}\right)$$

Interactive systems, especially microcomputers with graphical display in BASIC or TURBO-PASCAL languages are used in processing operations.

The possibility to make three consecutive equidistant "C" mode profiles on the same photograph allows to compute rail axis curvature when the tunnel goes through a curve, using formulae in Figure 3.



$$R' = \frac{c^2}{2a_1} \qquad R'' = \frac{c^2 - a_1^2}{a_2}$$

$$R_{1,2,3} = 1/2\,(R' + R'')$$

$$R_{3,4,5} = 1/2\,(R''' + R^{IV})$$

$$\vdots$$

$$R_{n-2,\,n-1,\,n} = 1/2\,(R^{K-1}, R^{K})$$

K = *current number of the photo.*

Figure 3 Rail axis curvature computation

The railway curve ray can be established by computing curvature values measured on all photographs, according to the regression curve:

$$R = \sum_{K=1}^{N} \left[\frac{1}{2K} \left(c^2 \sum_{i=1}^{n} \frac{1}{2a(K,i)} + \sum_{i=1}^{n} \frac{c^2 - a^2(Ki)}{a_{(x+1,i)}} \right) \right]$$

Railway axis eccentricity as against the tunnel arch key vertical is computed from the difference between X (key) - X (axis) coordinates, thus, allowing the real gauge dynamic visualization profile by profile, considering the cross tunnel section contours.

Considering an electrified line, the luminous spot specifies the free passing gauge as against the contact wire and the sustaining insulators.

Just the contact network point is measured as the highest contour point, the resulting gauge being so recorded in the profile file (Figure 4).

Conclusions

The photogrammetric method as against the classical ones has the following advantages when the inner tunnel gauge is to be established:
- low cost price;
- measurements are made in a short period of time, without stopping the railway traffic for a long time;
- a data bank development to monitor tunnel evolution in the course of time;
- a data bank development for free gauge in the tunnel. The routes for over gauge transport can be assigned, using proper

interactive programmes.
- the accuracy ellipse is established by values:

The maximum railway axis deviations as against the axis regression curve do not exceed 2.5 mm, thus, being within a $\pm$ 5 mm tolerance allowed by the present-day works.

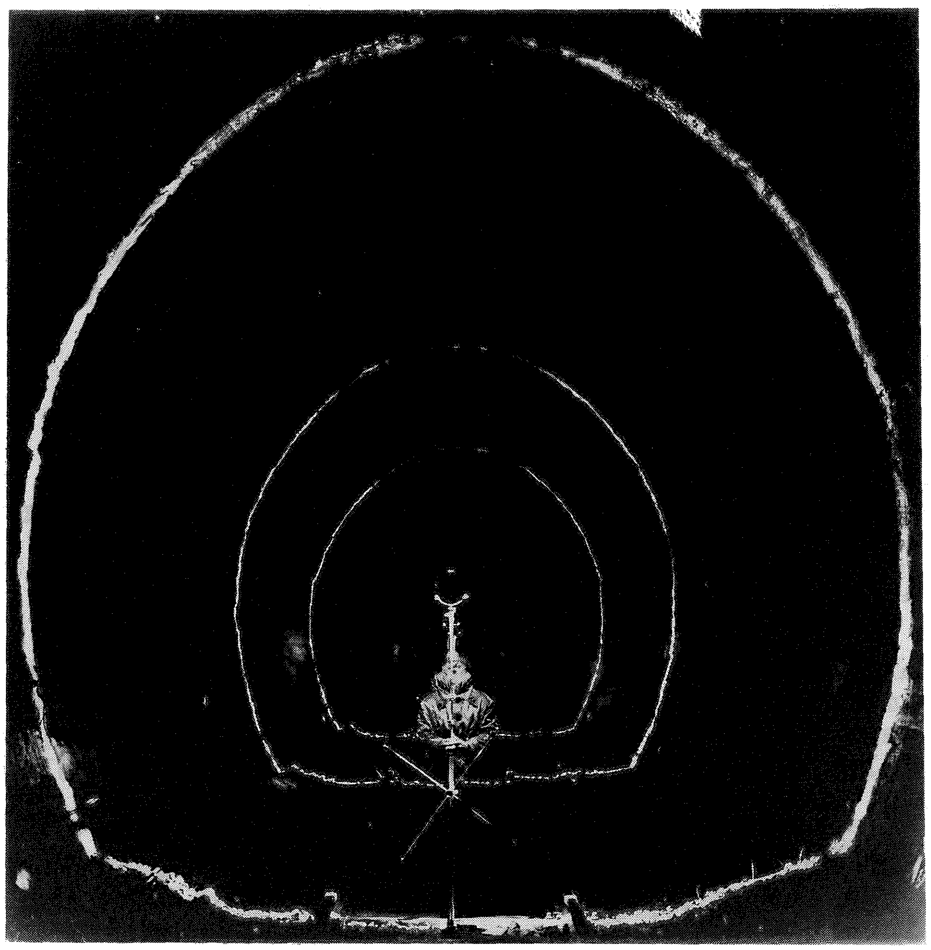


Figure 4 Contour recording on a WD plate

This method allowing to solve present-day running and maintenance problems represent another reason to photogrammetrically approach various technical and scientific fields of activity, in which case simple photogrammetric taking methods are assisted by computation interactive microsystems.

RÉSUMÉ: Les actions des agents physiques et tectoniques sur les tunnels de chemin de fer ont comme effet l'apparition de deformations dans la structure de résistance des anneaux constructifs. On décrit dans l'article la technologie de mesurage des profils transversaux dans les tunnels, utilisant des chambres métriques terrestres et des faisceaux actiniques dirigés.

Le traitement sur les systèmes interactifs de calcul réalise des profils numériques et graphiques, la dynamique des déformations des points de contrôle, les éléments geométriques de l'axe du chemin de fer, le profil, du gabarit libre de trafic, l'état géométrique de la ligne de contact pour l'électrification.

ZUSAMMENFASSUNG: Die physischen und tektonischen Einflüsse auf Eisenbahntunnels bewirken Deformationen in der Widerstandsstruktur der Bauringe. Man beschreibt die Messtechnologie der Querprofile in Tunnels mit terrestrischen metrischen Kammern und dirigierte aktinische Strahlenbündel. Die Datenverarbeitung durch interaktive Rechensysteme realisiert numerische und graphische Profile, die Deformationsdynamik der Kontrollpunkte, die geometrischen Elemente der Gleisachse, das Profil des Querschnittmasses für den Verkehr, die geometrische Lage der Kontaktlinie für die Elektrifizierung.