Geodetic surveying of crane trail space relations

Ľudovít Kovanič, ml.[1], *Juraj Gašinec*[2], *Ľudovít Kovanič*[3], *st., Peter Lechman*[4]

Geodet´s obvious task consists of surveying crane trails of different types. These transport machines must meet precise geometric parameters, considering mainly the safety of their operation. The paper describes several geodetic methods of determining deviations in direction and height of crane trails. Measurements were realized using special set of appliances composed for this purpose, as well as using electronic theodolite for measurements from hall floor. Results ofmeasurements were processed using calculation programe Geus, and graphicproramme Microstation. Used methods were compared in graphic form.

Key words: crane trail, direction deviation, height deviation, electronic theodolite

Introduction

Contemporary industry is quickly and extensivelly developping, simultaneously also the technology of manufacturing procedures and processes. Thus also demands on the accuracy of working machineries during their installation, as well as consequent controls of their appropriate operation are increasing. Therefore, geodets´cooperation during the assembly of several aplliances is of the utmostly necessity. This concerns mainly of crane tracks that before starting their operation must have their geometric parameters proved by geodets.

The paper deals with the issue of determination of space relations at the crane track situated in Delius pavilion of Mining faculty Technical University, Košice. First part of the paper deals generally with crane tracks characteristics, measurement methods used in practice for measurement of height and direction deviations, track gauge, and for measurements of parts of crane bridge that all are specified by instructions for measurement of geometric parameters of crane tracks.

The second part describes four measurement methods that were used in this particular case. For measurements were used: theodolite Theo 010B, universal measuring station (UMS) Leica TCR 305, Leica-Disto and levelling apparatus Zeiss Ni 020A. Measurement results are presented in graphic form in Appendices.

Assembly of machineries

At the assembly of a machinery we have to do mainly with the problem of determination of axes mutual position or with the task to meet specific geometric relationships. Construction conditions may be set up in several basic tasks, that are:

- alignment of collimating line (roll stands),
- alignment of parallels (rails of crane tracks),
- determination of verticality of objects (masts, chimneys),
- alignment of right angles (old rolling trains),
- determination of roundness (large pools, freezing towers),
- arrangement of points into straight line,
- alignment of given level (1).

Crane tracks

A crane track is often of key importance for intraplant transport. Very often, more cranes are installed on one crane track and failure of one of them does not mean necessary the interrruption of material transport, and consequently the interruption of the whole working process, but the crash of a crane track – for example formation of a fatigue rupture – may stop the operation of all cranes. This may lead to complete interruption of the production with catastrophic economic consequences. As examples may serve crane tracks in continuous metallurgical production – steel plants, stripping halls, ect., but also in single-shift or double-shift manufactures, see for example the crane crash in storehouses for reception and distribution of the raw material that is crucial for production. All these connections must be taken in account at investment activities, notably at designing and manufacturing of crane tracks (2).

[1] *Ing. Ľudovít Kovanič, PhD.,* ÚGK a GIS F BERG TU v Košiciach, Park Komenského 19,
[2] *doc. Ing. Juraj Gašinec, PhD.,* ÚGK a GIS F BERG TU v Košiciach, Park Komenského 19,
[3] *doc.Ing. Ľudovít Kovanič, CSc.,* ÚGK a GIS F BERG TU v Košiciach, Park Komenského 19,
[4] *Peter Lechman,* absolvent ÚGK a GIS F BERG TU v Košiciach
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At designing crane tracks must before their space adjustment and construction plan meet the following criteria:
a. safe operation of the crane traversing the crane track, mainly from the point of view of keeping to specified traversing crane profile, its running against a stop at final fields, crane overlaps, ect.,
b. safety of operation at manipulation, control and maintenance of the crane and crane tracks,
c. safety of operation under the crane tracks.

Also following factors must be met at designing crane tracks:
a. technology of manufacturing and operation in the crane track space,
b. basic module dimensions of the building according to STN 73 0005,
c. required parameters of operating cranes,
d. specified crane track tolerances,
e. requirements on rectification of crane tracks (3).

Repeated measurements of crane tracks using geodetic methods involve the control of following requirements for appropriate crane operation:
a. parallelity of rail axes,
b. horizontality of planes given by crane trail heads, and in some cases also,
c. control of verticality of the crane pillars on the crane track,
d. control of perpendicularity of final buffers to the crane track axis.

If measurement results must meet the utmost reachable accuracy, technical engineer must know not only all measurement tasks, but also the crane construction itself, operation of the crane, and possible faults that causes must be by geodetic methods identified (4).

Space design

Space design during crane track planning must first meet the criterion that none part of crane track construction, eventually other objects and machineries on the crane track interferes the profile that is given by crane contours magnificated by the sum of:
a. safe distance (of vertical and lateral gap),
b. the value of manufacturing assembling deviations of the crane track,
c. the value of required crane track rectification.

When under the crane track any transport exists, the construction neither of crane track nor the crane itself must by their contour magnificated by safety distance (vertical and lateral gap) interfere the passage gauge of supposed transport machine.

Surveying of crane tracks

Crane tracks are surveyed generally in following cases:
1. at building new tracks in the course of their building and constructing,
2. at newly builded tracks (without participation of a geodet) before putting the final construction into operation,
3. at prolonging and reconstructing of existing tracks,
4. for the control of operated tracks,
5. after crane crashes.

Ad 1. In the course of new tracks the following surveying works will be realized:
   a. position and height alignment of the axes for pillar footing blocks specified by plans (so called "foots" at crane tracks on steel supports on prefabricated ferroconcrete pillars),
   b. axis and height control of finished foots, laying out of axes for assembly of carrying pillars, and depending on investor requirments also the control of anchoraging holes,
   c. axis alignment for assembly of carrying pillars and crane-runway girders according to machine plan, eventually also alignment of parallel axis,
   d. cooperation at precise seating of the crane tracks on pillars,
   e. control measurements of the finished crane track.

Cooperation at assembly consists mainly of determination of mutual positions of opposite pillars, of identification of preliminary runway girders setting on pillars, and of the assessment of the extent in which parameters of support position enable laying out of crane-runway girders on the designed span. In case of contradiction between the project and realization of girders it is necessary to ask the investor to decide after the agreement between the designer and assemblying firm upon a compromise solution.

Ad 2. Surveying of the crane track after finishing building works. The final surveying report serve for documentation of the state of realized assembly of thre track and bridge at the approving procedure before passing off the finished structure into operation.

Ad 3. Surveying of the actual crane track before its reconstruction serves as a base for machine and building design works. According to design plans, axis and heights are aligned and are determined by fittings of steel constructions, mainly when the complete track can not be excluded from the working process, and reconstruction can be done only gradually, by sections in short time limits.

Ad 4. Measurements for identification of crane misoperation. Repeated measurements (at intervals ½ or once a year) control the impact of working operation on the track and bridges, and so such measurements are a necessary requirment for working maintenance, mainly in cases when from different reasons the operation of the crane is hightly exposed.

Ad 5. Measurement after crashes is realized when main runway girders were deformed, or crane bridge was derailed, ect (4),(8).

Tolerancies of crane tracks and rectification

Geometric shape of the crane track from the point of view of safe operation is specified by tollerancies (3) for construction, assembly and operation of the crane track. When during operation these tollerancies exceed a specified value, the crane track must be rectified.

Measurement of the crane track in Delius pavillion

Before of measurement of space relations of the crane track a reconnaissance of the crane track and its hall was done first. At reconnaissance, positions of points observed on the crane track were chosen, similarly the methods of measurements, positions of the apparatus during measurements, and what apparatuses and aids will be needed.

Methods that were chosen are as follows:

- measurement of horizontal deviations along the rail (line of sight),
- measurement of horizontal deviations from parallel axis,
- measurement of horizontal and height deviations from the floor using electronic tachymeter Leica TCR 305 (from two observation stations),
- measurement of horizontal deviations by the polar method,
- measurement of height deviations using technical levelling.

Before the measurement itself, the position of observed points on rails was marked. The left rail was chosen as the main rail and the right as a secondary one. On the beggining of main rail the first point, considered as a beggining of the collimation line, was marked, and nearly the end of main rail (approximatelly 4,5 m above the support) the second point, considered as the end of collimation line. The second point of collimation line was not chosen precisely at the end of rail, because at the end on the rail the crane technical operator put aside the crane bridge. Other detailed points serving for observation of deviations were along the whole rail over crane rail supports. Distances between points were aligned using standardized steel tape. After marking detailed points, the crane bridge was moved on the rail beggining and detailed points were marked at the rail end. The position of points in the middle of the rail was marked by rail scissors and dibber.

Using Theo 010 B that was fixed on the rail by the clamping board, a perpendicular lines from the beggining and ending point of collimation line to the secondary line were aligned. These secondary line ending points were on the rail marked in the same way as on the main rail. So the crane track was prepared for measurements.

Measurement of horizontal deviations using collimation line

For measurement Theo 010 B together with clamping device fixing it on the rail, milimeter gauge, and transportable level that puts the gauge into horizontal position were used.

Before the measurement itself, the system of coordinates (relation system) was determined. A positive axis +X was directed along the collimation line, and a positive axis +Y periperpendicularly on the collimatiion in the dextrorotatory direction.

The apparatus was put in the horizontal position and centered over the first point of main rail collimation line. Null reading was set up on the final point of collimation line. After those adjustements, the measurement of direction deviations of observed points has started,while the crane bridge was put aside at the end of crane track. Point deviations were read directly from the gauge, that was kept on the observed point and put into the horizontal position using the level. By gradual tilting the telescope and focusing it on the gauge, the value of shifts at observed points in positive or negative direction was read directly. Shift values were read twice, first reading toward the apparatus and the second one away from it. After measurement, the crane bridge was displaced on the beggining of the crane track. Then, using the clamping board, the apparatus was set up for measurement on the final point of collimation line. Apparatus orientation was performed at the last detailed point that was not overcovered by the crane bridge. The direction of orientation took in account the deviation at the observed point, so the alignment could be parallel with the axis of collimation line. The telescope was clapsed to the position that allowed reach the rail end, reading were done twice again (toward the apparatus and away from it). Final values were arithmetic averages of read values.

This procedure was repeated also on the parallel rail. Measured values were noted in the record book for purposes of graphic processing. Graphic processing of measurement results reached by the used method was done through graphic programe MicroStation (Appendix F/1).

Measurement of horizontal deviations using the method of retracted axis

This method of measurement is used mainly in situations where along the crane track a foot bridge isn´t at disposal or from other reasons it isn´t possible to measure deviations directly along the rail. This method is utilizable when on the lowered level of the crane track a floor exists, upon which it is possible to stabilize the retracted axis.

This method involves an alignment of parallels betwen the main and parallel axis of the crane track. At the first point of main rail collimation line, a helper kept the gauge in horizontal line with the aid of transportable level. Then, in the chosen distance at the gauge, the first point of collimation line was projected with the aid of a plumb onto the floor near the crane track. The point was stabilized by a nail beated into the wooden floor. The distance of retraction intentionally specified to allow pose the apparatus above the point (Fig. 1).

The second point of main rail collimation line was retracted in the same way in the same distance to secure the parallel relation between retracted and main axis, during this procedure the crane bridge was put off at the end of the crane track.

On the parallel rail, the beggining and ending point of the collimation line was retracted in the same way, and then stabilized similarly using the nail beaten into the wooden floor.

After retraction of both axes, Theo 010B was adjusted for measurements over the beggining point of the main retracted axis. Crane bridge was moved toward the end of crane track. The apparatus was oriented at the end point of retracted axis. During measurement of deviations, the gauge was kept in horizontal position using the level and shifts of points were read directly from the gauge tilting the theodolite telescope. Shift measurements proceeded in the same way as at measurements directly from the rail, first time toward the apparatus and second time away from it. After finishig the measurement, the crane bridge was transferred on the beggining of the crane track, the apparatus was put into horizontal position and centered on the end point of the retracted collimation line of the main rail, and was oriented on the beggining point of the retracted rail. In the same way, that is, by gradual tilting and transporting the gauge, final points of the main rail were measured.

After finishing measurement of the main rail, the crane bridge was transferred again on the end of the crane track. The theodolite was positioned on the beggining point of the retracted axis of the parallel line. Its orientation was realized at the final point, and by the same procedure as at the main rail, shifts of detailed points were measured. After finishing measurements from the beggining point of the retracted axis, the crane track bridge was transferred on the beggining of the crane track, the apparatus was put into horizontal position and centered at the final point of the retracted axis. The orientation was realized, and similarly as on the main rail, the end of the parallel line was measured.

Resulting shift values were calculated as arithmetic average of repeated measuments (forward and backward), and were noted into the record book to be able to process them in the graphic form in the programe Microstation (Appendix F/2).

Track gauge measurements

Track gauge measurements were performed at identical points that were used for deviation measurements directly on rails using the method of rectracted axis. The measurement were realized by laser apparatus Disto (distance meter), fy. Leica and a reflex plate for better beam reflexion.

Disto was adjusted over the points of main rail, its front side was made identical with the position of the point, and on the parallel line, a helper kept the reflex plate over points. Measurement of track gauge was realized twice, one measurement from one rail, and the other by measurement from the second one. Using Disto, also distances from beggining and final rail points till the buffer of crane track were measured, again they were measured twice. Resulting lenght values were arithmetic averages of measured values, and found differences didn´t reach more that two millimeters.

Measurement of horizontal and height deviations using electronic tachymeter Leica TCR 305 from ground

At this procedure, stations of apparatus (electronic tachymeter Leica TCR 305) were determined and stabilized after the terrain reconassaince. Operation space of stations (5001, 5002) wasn´t blocked by any other hall devices. Before the measurement, the crane bridge was transferred on the end of the crane track. The apparatus was put into the horizontal position and centered at the station No. 5001, from here, horizontal and height shifts of main rail were specified. The polar method with simultanous measurement of height (zenith) angles fom measurement of height shifts were used. Setting up the apparatus enable immediate reading of coordinates, because the measurement was realized in the coordinate ang height system. Apparatus was oriented at the station No. 5002 and for measurement the miniprism was used. Measurement proceeded gradually from the beggining of the rail, until the crane bridge didn´t appeared as an obstacle. Then it was transferred with the help of crane technician on the beggining of the rail, and resting points of the main rail were measured. After finishing the main rail measurement the apparatus was put into horizontal position and centered on the station No. 5002, and orientation was realized at the station No. 5001. The crane bridge was still standing at the beggining of the crane track, therefore the measurement of assessed points has started by the end of parallel line until again the crane bridge didn´t obstruct the work, which was then again moved to the end of the crane track, and so enable the measurement of resting points of parallel line. All coordinates X, Y, Z measured in their own coordinate systems were noted into the record book for graphic processing of position and height shifts of observed points (6), (7). (Appendix F/3).

Measurement of horizontal deviations by polar method

This method of shift measurement of observed points has several possibilities. When conditions are suitable, it can be realized from one or from two stations appropriately located in the manufacturing hall. For our purposes the polar method with the apparatus fastened at the rail of the crane track with the help of fastening plate was used (Fig. 2).

Fig. 1. Theodolite position at retracted axis.

Fig. 2. Leica TCR 305 fastened at rail.

Leica TCR 305 with reflex miniprism was used, and the same stations that were used at the previous procedure and identical own coordinate (relation) and height system were used for measurements. Before the beggining of measurements the apparatus was fastened by fastening plate at the ending observed point (detailed point No. 18) on the parallel rail, while the crane bridge was put aside at the beggining of the crane track. Coordinates of the stations and orienting points (5001, 5002) were took over from measurements by electronic tachymeter Leica TCR 305 from the ground. After adjustement of the apparatus at the ending point of the parallel rail, the orientation was realized on the stabilized point (No. 5002) in the hall floor, and gradually all assessed points of the main and parallel that were not overcovered by the standing crane bridge were measured.

The crane bridge was transported to the end of the crane track, and the apparatus was adjusted for measurements on the observing point No. 3 that was located on the main rail of the crane track. The orientation was transferred onto the point No. 5001, and beggining points of the main rail (1,2) were completed, and as a control, all reachable points of the main rail. The control assessment of parallel rail points cannot be realized because of insufficient working space for the apparatus operator (rail is installed nearly the hall wall).

For completing beggining points (10,11) of the parallel rail, the apparatus was put into the horizontal position and centered on the beggining point (No.1) of the main rail and the orientation was realized toward the point No. 5001. So beggining points were completed, and for the control also all reachable points of parallel rail not overcovered by the crane bridge.

All measured values were noted in the record book for purposes of their further calculations and graphic processing. Calculations were realized in the programe Geus, and graphic processing using the programe Microstation (Appendix F/4).

Measurement of height deviations using technical levelling

For assessment of height deviations and mutual relative height of observed points, the technical levelling using the apparatus Zeiss Ni 020A was used. The levelling apparatus was put into horizontal position on the crane bridge placed at the beggining of the crane track. Gradually, all points that weren´t overcovered by the crane bridge were aligned. For alignment of resting points it was necessary to transport the crane bridge on the end of the crane track. There the levelling apparatus was again put into horizontal position. Because the collimation axis of the levelling apparatus was in different height in comparison with the collimation axis of the apparatus set up on the first station, it was necessary to aligne at least one, already aligned detailed point. Then, all resting detailed points that wasn´t possible to measure from the first station of the levelling apparatus were aligned. All measured values were noted into the technical levelling record book enable so their calculation and graphic processing.

Comparison of used methods

At measurements of the crane track space relations in Delius pavillion we used several methods of direction and height deviation measurements that were in detail described above. In practice, one may use any of these methods, but the choice of the most suitable one depends on specific crane track, that should be aligned. If foot bridges exist below the crane track over the ground or if the crane track is put on the floor of assemblying hall, measurement of direction deviations by the method of collimation line with positioning of the apparatus directly on the crane track rail, is the most suitable and mostly precise method. Advantage of this method is that point shifts are assessed directly during measurement, and no calculations are needed. Height deviation are assessed usually by using technical levelling, locating the apparatus on the crane bridge, eventually on any platform nearby the crane track. When it isn´t possible to measure deviations directly from the rail, we suggest to use the method of the collimation line retracted by specific appropriately chosen distance parallel with the main collimation line. This way is used mainly when nearby the crane track either a foot bridge or any floor exists that allows the stabilization of the retracted collimation line. Also at this method one may directly during the measurement assess direction deviations of observed points, and no other calculations are needed. Errors may occur when the gauge isn´t kept horizontally on observed points. For measurement of height deviations the technical levelling will be used.

The polar method is the other one used in practice.At present for measurements by the polar method UMS are used, that are very precise and except of measurements of direction deviations enable simultaneously the measurements of height deviations. Apparatus stations are determined according to specific conditions, that is either directly on the rail or on the floor of assemblying hall. Measurements are realized usually in their own coordinate system. Shifts in direction and height are reached by numerical processing of measured values.

Often, the crane tracks are set up at the elevated level and above mentioned methods cannot be used from different reasons, for example nearby the crane track there is no platform where the collimation line could be retracted, there is not enough space for the apparatus establishment, or such work wouldn´t be safe for the operator. In these situations the most suitable method is the procedure of measurement direction and height deviations using UMS. Stations are usually chosen on the ground approximately in longitudinal axis of the crane track. Resulting values of horizontal and height shifts can be at disposal only after processing of measured values. At appropriate setting up the apparatus we may at measurement directly reach coordinates X,Y,Z of measured points.

Evaluation of used methods

<u>Limiting horizontal deviation of longitudinal rail central line from designed axis for crane tracks till 100m (10mm)</u>

- at measurement directly on the rail using collimation line these deviation limits are kept at all points of the crane track,
- at measurement using retracted axis of collimation line these deviation limits are kept at all points of the crane track,
- at measurement point deviations using electronic tachymeter Leica TCR 305 from ground are these deviation limites kept at all observed points,
- at measurement using the polar method deviation limits are kept at all observed points.

<u>Limiting height deviation from horizontal plane of rail running parts of crane track branches for crane track till 100 m (5 mm)</u>

- at measurements directly on the rail using collimation line these height deviations are not kept at points 1, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17 and 18,
- at measurements using retracted axis of collimation line, limits are not kept at points 1, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17 and 18,
- at measurement point deviation using electronic tachymeter Leica TCR 305 from ground these deviation limits are not kept at points 6, 8, 10, 11, 12, 13, 14, 15, 16, 17 and 18,
- at measurement using the polar method these height deviation limits are not kept at points 1, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17 and 18.

<u>Limiting height difference of the right and left branch of the crane track in diagonal direction (5 mm)</u>

- at measurements directly on the rail using collimation line limiting difference isn´t kept between points 3-12, 4-13, 7-16, 8-17, 9-18,
- at measurements using retracted axis of collimation line, limits of difference are not kept between points 3-12,4-13, 7-16, 8-17, 9-18,
- at measurement point deviation using electronic tachymeter Leica TCR 305 from ground the limiting difference isn´t kept between points 2-11, 3-12, 4-13, 7-16, 9-18,
- at measurement using the polar method the limiting difference isn´t kept between points 3-12, 4-13, 7-16, 8-17, 9-18.

<u>Limits of deviations at crane track gauge till 20 m (5 mm)</u>

- at measurement directly on the rail using collimation line is the limit of deviations kept at all points,
- at measurement using the retracted axis of collimation line is the limit of deviations kept at all points,
- at measurement point deviations using Leica TCR 305 from ground the limiting deviation isn´t kept between points 9-18,
- at measurement using the polar method this limiting deviation isn´t kept between points 3-12, 5-14, 6-15, 8-17, 9-18.

Measuring the crane track in Delius pavillion of Mining faculty TU, Košice using several methods we found, that the crane track as to horizontal deviations meets specification criteria for crane track with the lenght till 100 m and track gauge till 20 m. Height shifts of some observed points are markable, therefore it would be suitable to rectificate it. Limiting distance difference of buffer faces from the plane perpendicular to the crane track axis (10 mm) don´t meet buffers at the beggining of the crane track, ending buffers met these limits. Considering the safety of operation, it would be suitable to repair buffers at the beggining of the crane track according to limiting deviations.

Among used methods, the polar method appears to be least precise. After processing of measurement results reached by this method, we found that observed points showed the highest shifts in comparison with other methods. The reason of these differences could be done by steep collimation orientation at measurements, as well as the fact that detailed points of the crane track were measured from several stations positioned at rail of the crane track. This way the orientation and centration of the apparatus might be erroneous.

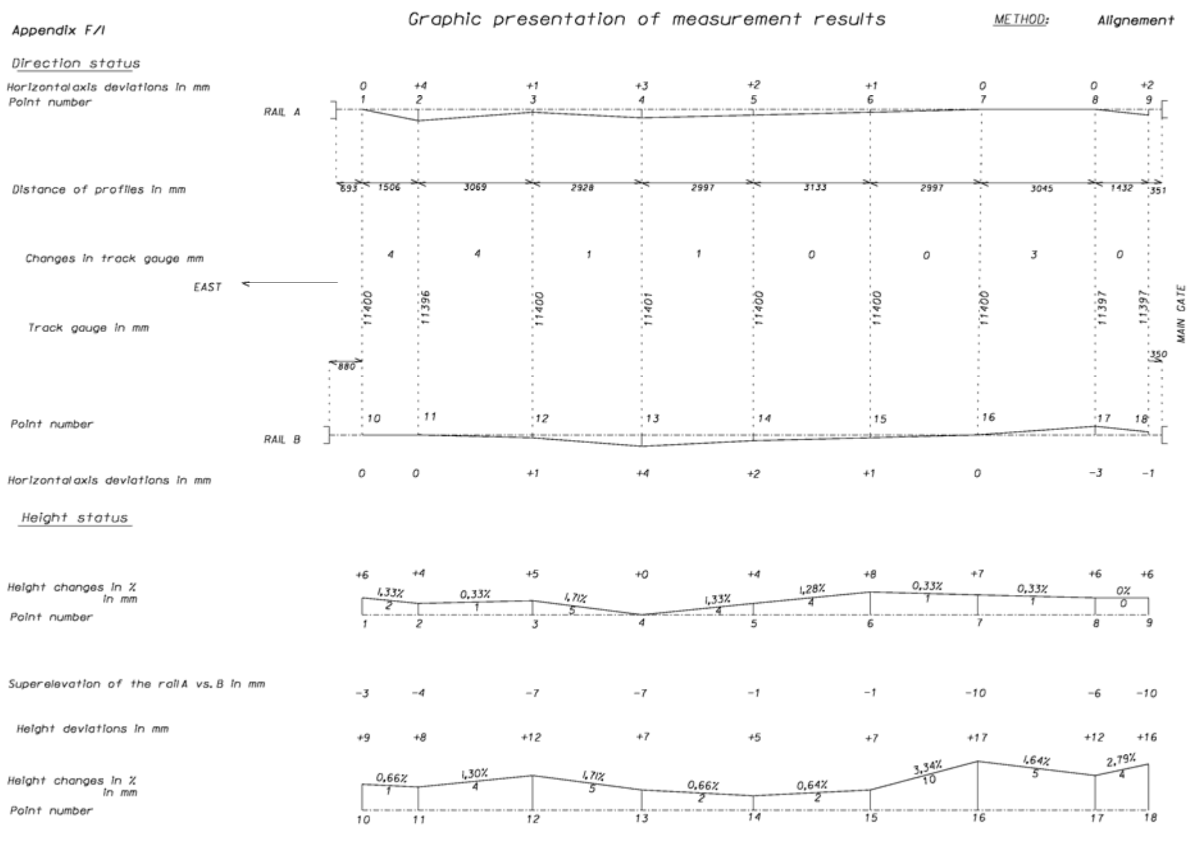
Appendices show graphic presentation of all used methods, as well as their mutual comparison. The same crane track was assessed in 2008 (diploma thesis), results of their comparison are presented in the Appendix F/6, F/7.

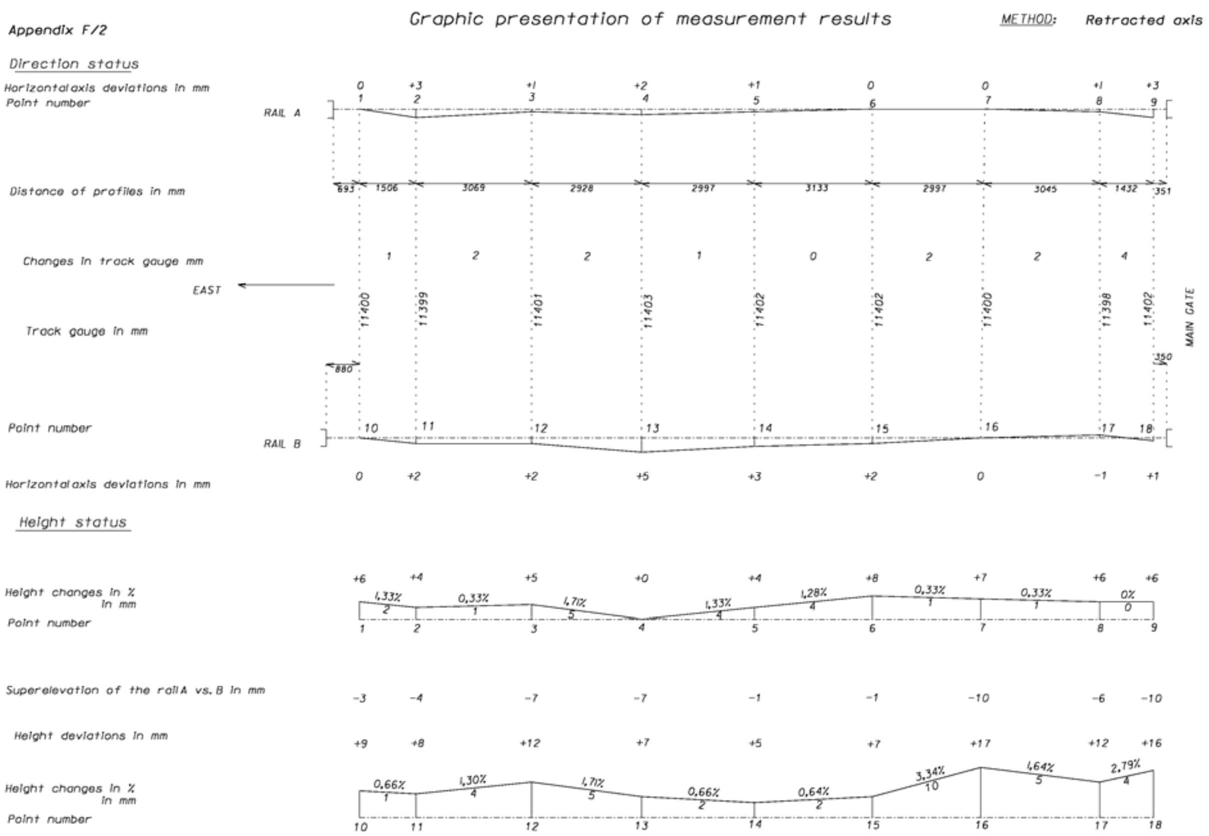
Conclusion

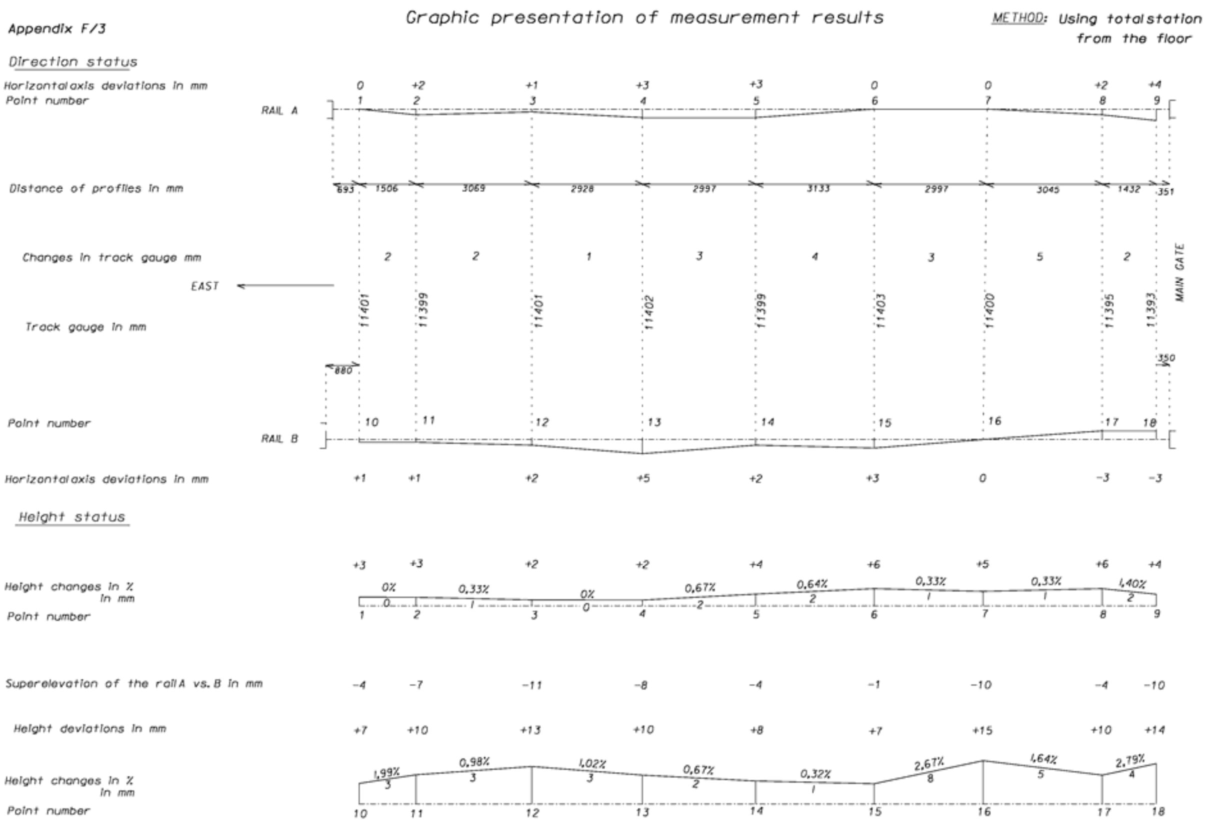
Our aim was to assess space relations of the crane track in Delius pavillion of the Mining faculty TU, Košice. The paper describes the course of measurements and methods used for determination of space relations at the crane track. Measurement results reached by individual methods were mutually compared, simultaneously the comparison of our average measurement values with average values of similar measurement from 2008 is presented [5].

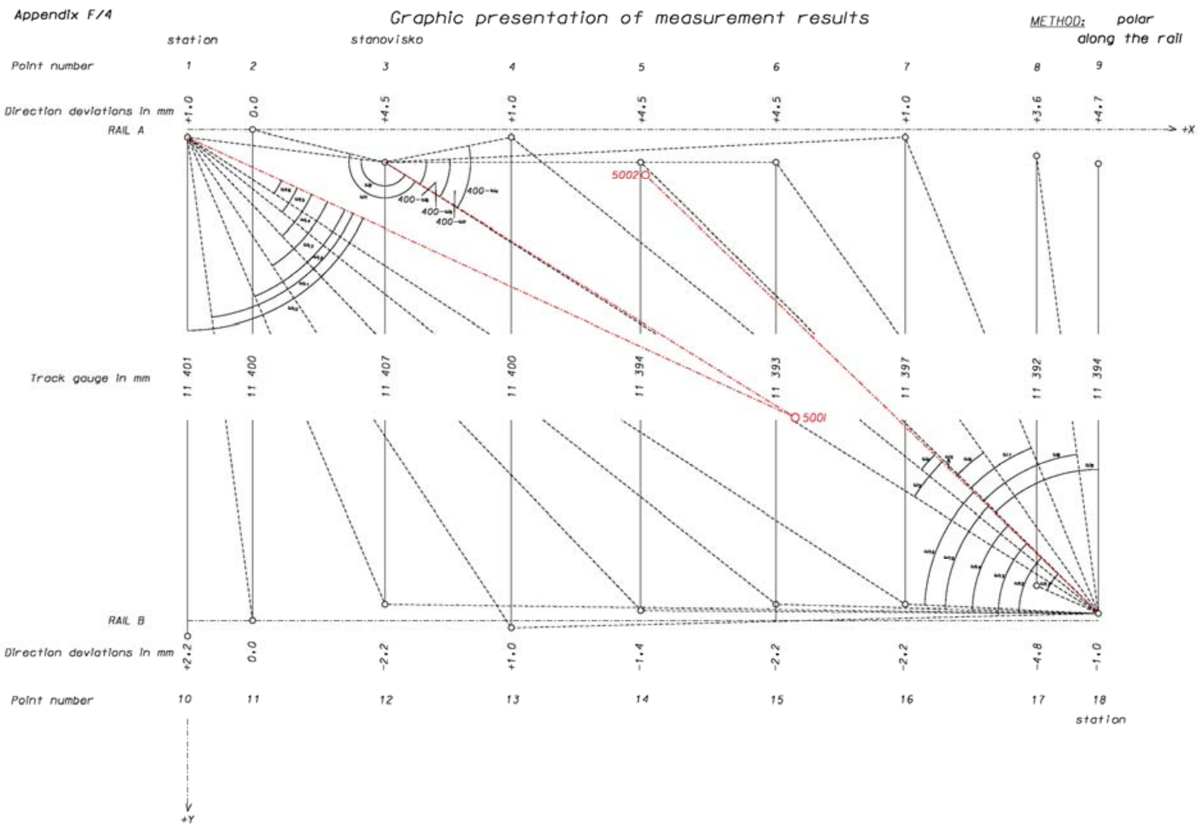
Results of individual methods are slightly different, that can be given by measurement errors, or by the accuracy of the method itself. As the most precise method we may consider the method of shifts measurement directly on the rail using collimation line, because here is the least probability of errors, and values of direction shifts are reached immediately during the measurement. On the other side, as the least precise, the polar method appears, mainly because its usage is limited by insuficient working space along rails of the crane track.

At present, the development of measuring apparatuses is accelerated, today they involve sophisticated softwares, and accuracy of measurements is increasing, therefore also each chosen individual procedure of measurement gives more and more precise results.

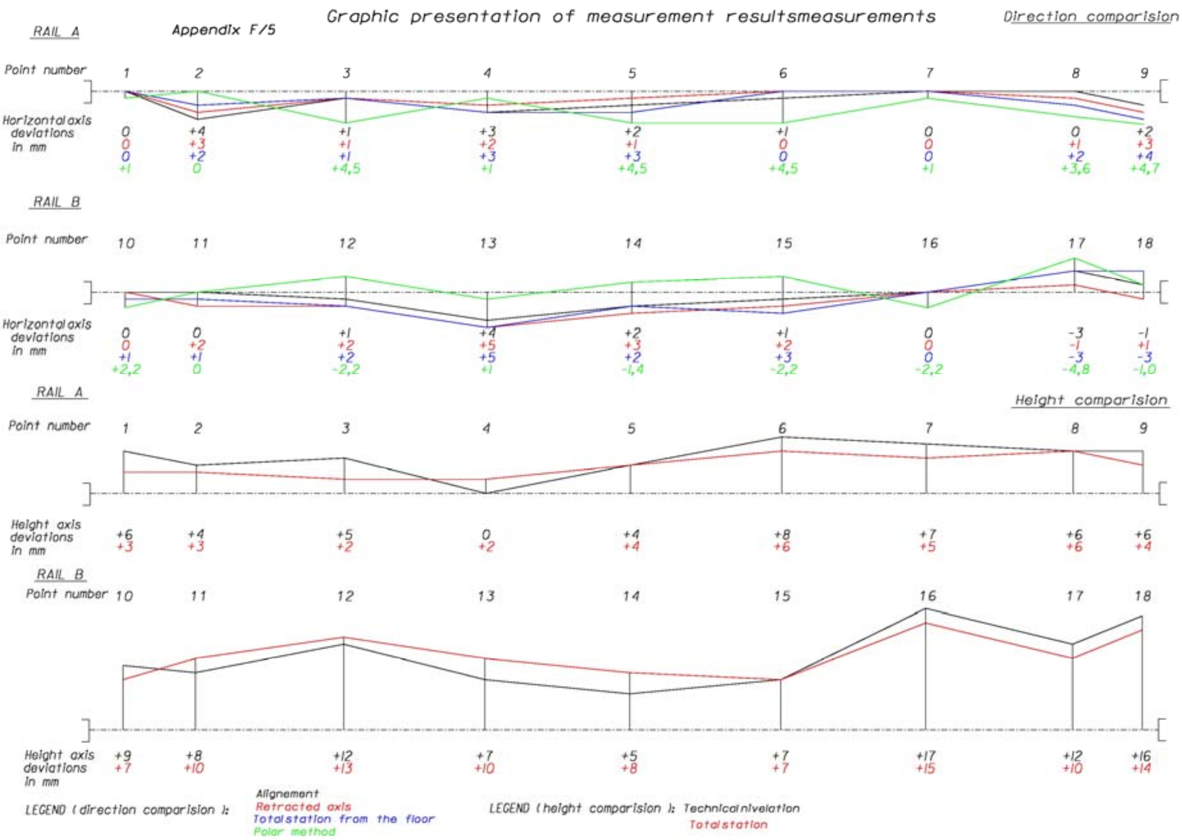



Appendix F/2
Graphic presentation of measurement results
METHOD: Retracted axis
Direction status
Horizontal axis deviations in mm
Point number
RAIL A
Distance of profiles in mm
Changes in track gauge mm
EAST
Track gauge in mm
MAIN GATE
Point number
RAIL B
Horizontal axis deviations in mm
Height status
Height changes in % in mm
Point number
Superelevation of the rail A vs. B in mm
Height deviations in mm
Height changes in % in mm
Point number

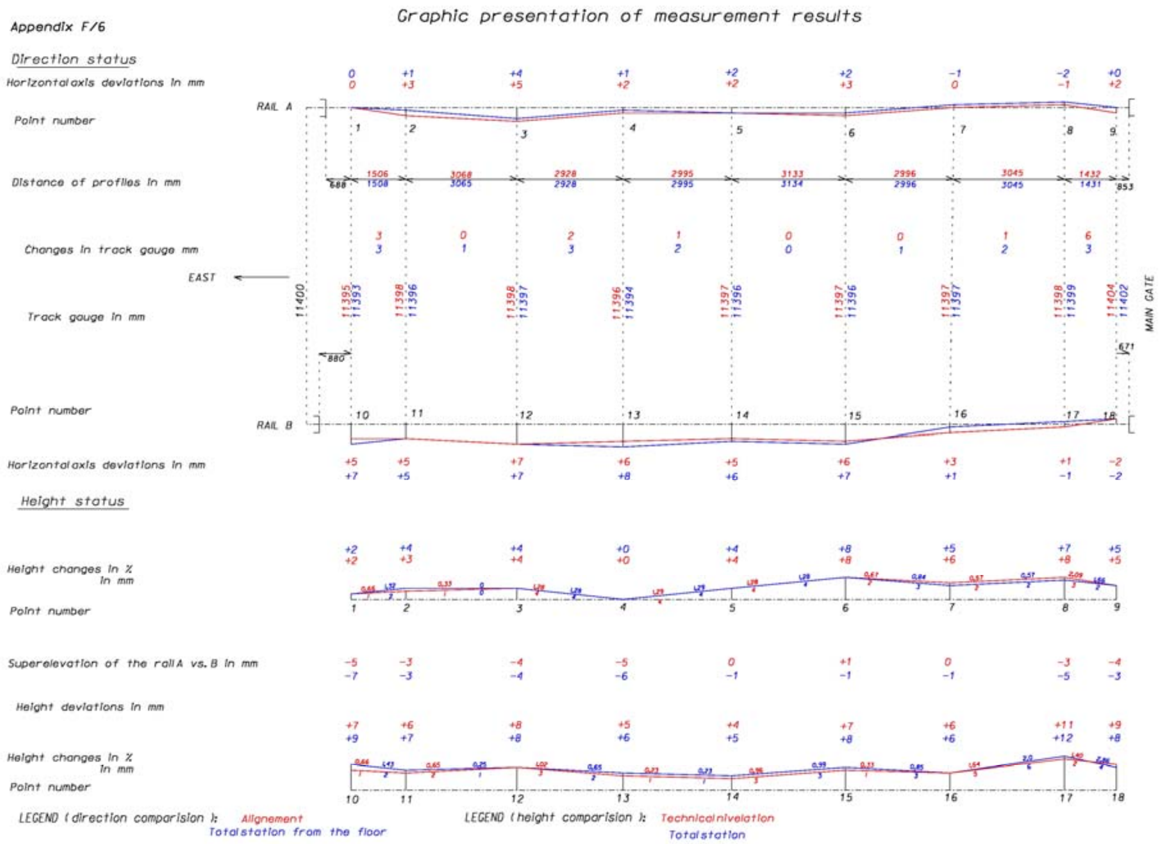

Appendix F/3
Graphic presentation of measurement results
METHOD: Using total station from the floor
Direction status
Horizontal axis deviations in mm
Point number
RAIL A
Distance of profiles in mm
Changes in track gauge mm
EAST
Track gauge in mm
MAIN GATE
Point number
RAIL B
Horizontal axis deviations in mm
Height status
Height changes in % in mm
Point number
Superelevation of the rail A vs. B in mm
Height deviations in mm
Height changes in % in mm
Point number

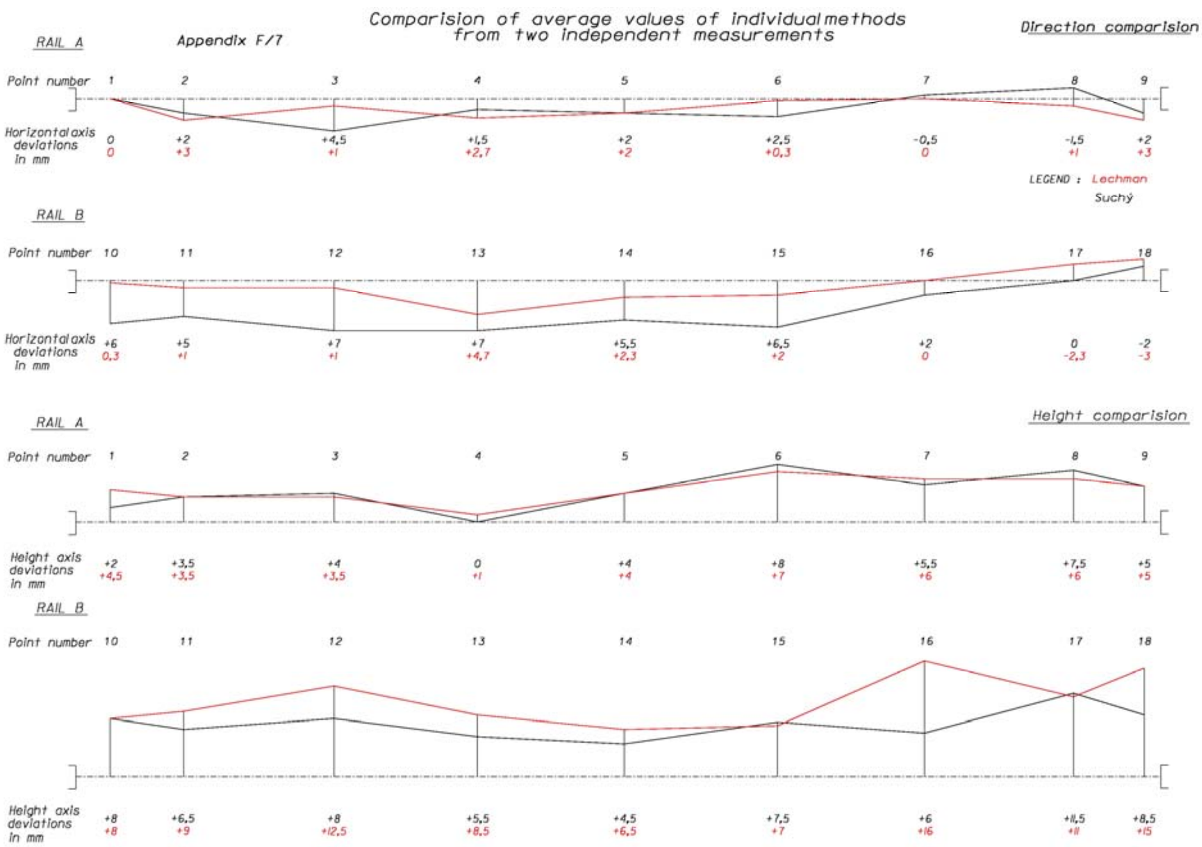


Appendix F/4
Graphic presentation of measurement results
METHOD: polar
along the rail
station
stanovisko
Point number
Direction deviations in mm
RAIL A
+X
5002
Track gauge in mm
11 401
11 400
11 407
11 400
11 394
11 393
11 397
11 392
11 394
5001
RAIL B
Direction deviations in mm
Point number
station
+Y



Graphic presentation of measurement resultsmeasurements
Appendix F/5
Direction comparision
RAIL A
Point number
Horizontal axis deviations in mm
RAIL B
Point number
Horizontal axis deviations in mm
RAIL A
Height comparision
Point number
Height axis deviations in mm
RAIL B
Point number
Height axis deviations in mm
LEGEND (direction comparision):
Alignement
Retracted axis
Totalstation from the floor
Polar method
LEGEND (height comparision): Technicalnivelation
Totalstation


Appendix F/6
Graphic presentation of measurement results
Direction status
Horizontal axis deviations in mm
Point number
RAIL A
Distance of profiles in mm
Changes in track gauge mm
EAST
Track gauge in mm
MAIN GATE
Point number
RAIL B
Horizontal axis deviations in mm
Height status
Height changes in %
in mm
Point number
Superelevation of the rail A vs. B in mm
Height deviations in mm
Height changes in %
in mm
Point number
LEGEND (direction comparision): Alignement
Total station from the floor
LEGEND (height comparision): Technical nivelation
Total station


Comparision of average values of individual methods
from two independent measurements
Appendix F/7
Direction comparision
RAIL A
Point number
Horizontal axis deviations in mm
LEGEND : Lechman
Suchý
RAIL B
Point number
Horizontal axis deviations in mm
Height comparision
RAIL A
Point number
Height axis deviations in mm
RAIL B
Point number
Height axis deviations in mm

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