Rectification of walls of the historical brick barrack on the site of the former German Nazi Concentration and Extermination Camp KL Auschwitz - Birkenau

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Abstract. The construction of the German Nazi concentration and extermination camp Auschwitz II - Birkenau started at the end of 1941. A barrack with the current inventory no. B-123, situated at the section BI, was then erected. The barrack has a documentary and historical value. The barrack walls are characterised by the low stiffness, because with the building’s plan of 36.17 m × 11.39 m, the walls are only 0.12 m thick. All the outer walls have been substantially deformed or vertically deflected. Up to 100 mm wide gaps have formed between the deformed and deflected external walls and contiguous walls as a result. The stability of the walls was at risk, because a bad-quality wall was loaded with horizontal and vertical forces transmitted from the roof on the eccentricity reaching 100 mm. Deformations were progressing over time as a consequence of such forces. Individual rectification procedures were designed and implemented for each wall as part of the comprehensive conservatory and building works, the purpose of which was to ensure the stability. This article presents a procedure of rectification the eastern gable wall and the outer, longitudinal northern wall. The deformation of the eastern gable wall was removed by changing its static scheme, by inserting hinge regions into the wall along the line of selected bed joints. Separate wall patches, which could rotate relative to each other, were created as a result of the forces acting perpendicular to the wall surface. By causing the mutual rotation of such patches, the eastern gable wall reached the desired vertical position. The vertically deflected, longitudinal outer northern wall was rectified by rotating the wall in relation to the wall support edge on the foundations. An analogous procedure was applied to the outer longitudinal southern wall. After the completed rectification, the walls were anchored to the contiguous walls; the places of rotation and anchoring were filled with mortar. A different procedure was adopted for the other deflected walls. The advancing deformations of the western gable wall were stopped by stabilising its position with the steel elements connected with ties anchored in the ground. It was inadmissible to rectify this wall because it is covered with plaster and paint coats with a high historical value.

1. Introduction
A barrack with the current inventory number B-123 (camp number 8) is situated at the section BI of former KL Auschwitz II – Birkenau. The German Nazi Concentration and Extermination Camp Auschwitz–Birkenau operated in 1940 – 1945 and was the largest German concentration camp [1]. Since 1947, the campsite together with all the structures has been under the custody of the Museum created at that time. Since 1979, it is inscribed to the UNESCO World Heritage List, and to the monuments register since 1995.
All the outer walls of the barrack B-123 - two gable walls and two longitudinal walls have been deformed and deflected. The state of the walls threatened their stability and it was necessary to carry out works involving the elimination of deformations and stabilisation of their position. A standard approach to deflected walls [2], involving their disassembly and reconstruction in a vertical position, was not possible due to the site's unique and historical character and inconsistency with the Museum's ethical principles and conservatory practices. Therefore, a dedicated individual procedure was designed and implemented for each of the walls. The western gable wall, covered inside with plaster and paint coats of great historical importance, was stabilised and reinforced by installing a steel construction from outside, mounted by means of rods to the foundation made inside the building. This way, interference in the original layers on the walls was limited as far as possible. The design of this solution is shown in [3].

This paper outlines a procedure of handling the eastern gable wall and the longitudinal walls - using the example of the northern wall. Position rectification was designed and then carried out for such walls. This approach is unique because the rectification of building elements has not been used until now, and before the procedure covered the entire body of the building. This application of rectification is described more widely in [4] and [5].

2. Description of the barrack with inv. no. B-123

The barrack has no basement, and has a rectangular plan of 36.37 m × 11.43 m and a height of 5.27 m. 0.12 m thick barrack walls are made of full brick. Pilasters with the section of, respectively, 0.38 m × 0.38 m and 0.25 m × 0.25 m, are located in the outer gable walls (Figure 1 - walls in axes 1 and 10) and in lateral inner walls (Figure 1 - walls in axes 2 - 9). The structure of the roof, covered with concrete tiles consists of a wooden formwork with a queen post system. The main trusses, consisting of posts, a pair of rafters and two pairs of (upper and lower) collar ties are in the axes 2 – 9, spaced every about 4 m (Figure 1). The rafters installed between the main trusses are spaced every 0.80 m. The purlins rested on the posts and supported with angle braces run in the axes B and D (Figure 2). It is very important to notice that the individual angle braces have an effect on the gable walls. The unbalanced horizontal forces transmitted from the angle braces to the gable walls had initiated a deformation process of these walls.

Wall plates are placed on the outer longitudinal walls (walls in axes A and E - Figure 1), to which rafters are mounted. The rafters’ transmitted horizontal forces onto the outer longitudinal walls, causing their deflection. The inner longitudinal wall (the wall in the axis C – Figure 1) acts as a stiffening wall. The other barrack walls act as partition walls. The bearing walls are founded on foundation walls made of full ceramic bricks with the section of 0.25 m × 0.43 m and on concrete footings located lower with the section of 0.40 m × 0.46 m. Window and door openings are located in the outer longitudinal walls. Wall plates are used as window and door lintels in such walls. Two window openings with masonry lintels made above them are located in the gable walls.
Figure 1. View of the barrack; cross-section A – A is given in Figure 2: 1 – eastern gable wall, 2 – outer, longitudinal northern wall, 3 – gap of a width of up to 100 mm between the gable wall and inner longitudinal wall, 4 – gaps of the width of up to 40 mm between the outer, longitudinal northern wall and the inner lateral walls.

Figure 2. Cross-section of the barrack, the section location is shown in Figure 1

3. Main damages in the barrack
The barracks had numerous damages of structural and non-structural components, as described more broadly in [3]. The damages endangering the structure stability were deformations of gable walls and deflections of outer longitudinal walls.

The gable walls situated in the axes 1 and 10 have detached from the inner longitudinal wall running in the axis C. Moreover, the walls were deformed to such an extent that their bending in the horizontal direction, near their mid-length, was characterised by the deflection $u_{\text{max}}$ of 100 mm (section A – A in Figure 3). It should be noted that the lower edge of the gable wall has not displaced in relation to its upper edge. This is due to the fact that the lower edge is based on the foundation, and the supports of the upper edge consist of purlins. An image wall deformation in the form of an isoline of displacements, prepared on the basis of the examination by the point cloud method, is shown in Figure 3.
The dominant causes of the eastern gable wall’s damage are second-order deformations. The following factors had an effect on the intensity of the observed damages: transmission of a horizontal load onto the wall from the angle braces of the roof formwork (1 - Figure 3), transmission of vertical loads by the wall, transferred eccentrically from the posts of the roof formwork, rheological effects taking place in the wall material and the created secondary static scheme of the gable walls after their detachment from the longitudinal walls. As a consequence of the advancing rheological processes, eccentricities were growing, influenced by vertical forces. This, in turn, resulted in the intensification of wall deformation in the middle of its buckling length.

An outward deflection of the northern outer wall occurred. The maximum value of the horizontal displacement of the upper edge of the wall was 40 mm (cross-section A - A in Figure 4). This deflection occurred due to the acting horizontal unbalanced force transmitted by the rafters rested on the wall, through the wall plate. Gaps with the width of up to 40 mm were formed due to the simultaneous separation of the longitudinal wall from the lateral walls. The values of horizontal displacements of the wall are shown in Figure 4 as contours prepared on the basis of the examination by the point cloud method.

![Figure 3](image)

**Figure 3.** An image of deformations of the eastern gable wall in the form of an isoline and cross-section A – A through the wall; 1 – angle brace of the wooden roof structure transmitting horizontal loads onto the gable wall
Figure 4. Deflection of the central part of the outer longitudinal northern wall (isolines) and the cross-section A - A through the wall; 1 - rafter of the wooden roof structure transmitting horizontal loads onto the longitudinal wall

4. Rectification of the eastern gable wall
The eastern gable wall (the wall in axis 10) was reconstructed in the past and is deprived of any historical plaster or paint layers. Deformation removal through rectification and then stabilisation was designed for the wall. It was assumed that to remove the wall deformation, horizontal forces perpendicular to the wall surface have to act on the wall. A retaining construction was built in order to balance the horizontal forces, and a wooden model was made before building the construction. The construction finally consisted of several parts: five buffer stops (1 - Figure 5) anchored to concrete blocks (2), horizontal beams (3) running parallel to the wall and mounted to the buffer stops, bracings (4) and a scaffold inside the building (5). Perpendicular forces acting on the walls were caused by screw jacks (6). The jacks, mounted to horizontal beams, were transmitting loads onto the wall through wooden spacers (7).
Figure 5. Scheme of the steel retaining construction built by the eastern gable wall: 1 – buffer stops consisting of four triangle-shaped components, 2 – concrete blocks, 3 – horizontal beam, 4 - bracings, 5 – scaffold inside the barrack, 6a – screw jack where the acting force was generated, 6b – screw jack acting as a support, 7 – wooden spacers, 8 – reinforcement provided in bed joints after removing the wall deflection.

The wall behaviour during the planned rectification was analysed with calculations before starting the works. A computational model of the wall shown in Figure 6a was built for this purpose. The forces $Q_1$, $Q_2$, $Q_3$, acting in the direction of the axis $y$, were applied to the model in the middle of the wall height, in the places of the planned installation of active screw jacks (6a - Figure 5). Hinged supports in the upper edge of the wall were assumed in the places where jacks were placed, acting as supports in the model. The values of the forces $Q_1$, $Q_2$, $Q_3$ were matched in such a way that horizontal displacements with the value of $u_{max} = 100$ mm are caused in the middle of the wall length. By applying such a load, bending moments were generated, acting in the plane $zy$, with considerable values in the place of wall installation in the foundation (Figure 6b). The gable wall is unable to transfer such moments. It was assumed that during the removal of the deflection in this point, bed joints will be significantly widened and hinge regions will appear. The patches of the wall separated between the hinge regions will rotate intensively as a consequence. A potential free rotation of the wall was therefore assumed in this place in the second step of calculations (Figure 7a). After applying loads to this model again and after forcing the displacements $u_{max}$ with a set of forces, considerable moments were identified in the point of application of the forces $Q_1$, $Q_2$, $Q_3$ (Figure 7b). It was hence assumed that intensive rotations of the wall cross-sections will also occur in this place in the structure being rectified. One could assume that after removing the deflection, areas of intensive deformations – hinge regions will appear in two points of the walls (Figure 8), and the wall parts between the hinge regions will behave as rigid patches.

Figure 6. Analysis of the model of western gable wall loaded with horizontal forces – phase 1: a) model scheme, b) distribution of bending moments acting in the plane $zy$ (values of moments in wall installation to the foundation exceed the bearing capacity of the wall to bending)

Figure 7. Analysis of the model of western gable wall loaded with horizontal forces – phase 2: a) model scheme, b) distribution of bending moments acting in the plane $ZY$ (values of moments in the point of load application exceed the bearing capacity of the wall to bending)
It was found in the course of rectification that the wall behaves according to the calculations carried out previously. Bed joints were significantly widened in the point where the wall rests on the foundation and in the point where horizontal forces were applied. After the rectification carried out, the widened bed joints were refilled, and the whole wall was anchored to the longitudinal wall running is the axis C and to a pillar with a reinforced concrete core mounted for this purpose (I – Figure 9). As mentioned above, anchoring consisted of inserting the rods into bed joints along the entire height of the wall, with the rods connecting the gable wall with the longitudinal wall. The applied shapes of spiral rods with the diameter # 4.5 mm made of austenitic steel are shown in Figure 9. Figure 10a shows the wall during rectification, and the wall after stabilisation in the new position is shown in Figure 10b.
5. Rectification of the longitudinal northern outer wall

The deformation of the longitudinal outer northern wall resulting in its deflection to the outside was removed by acting with horizontal forces onto it. The steel construction was mounted along the wall for this purpose (Figure 11). The construction consisted of twelve steel frames. Each frame consisted of three parts: a horizontal beam anchored to the concrete elements arranged on the ground, a vertical column and a strut. Three steel beams running horizontally, made of a U-shaped profile, were attached to the posts of all frames. A wooden element was placed inside the profile, to which screw jacks were attached in turn. Impact on the wall was exerted in the horizontal direction by increasing the force in the jack. The force applied caused the rotation of the wall in relation to the foundation. After rectification of the wall, the bed joint, which was widened by the action of the forces and the rotation of the wall, was filled with modified mortar. The wall was then anchored to the lateral walls, by means of spiral rods 4.5 mm made of austenitic steel (6 - Figure 11). The photographs in Figure 12 show the wall during the rectification and after its completion and disassembly of the steel construction.

Figure 10. The gable eastern wall of the barrack: a) retaining steel construction built by the wall for rectification, b) after removal of deflection and stabilisation
Figure 11. Scheme of the steel retaining construction built by the longitudinal wall: 1 – buffer stops, 2 – concrete blocks, 3 - horizontal beam, 4 – wooden spacers, 5a – screw jack where force was generated, 5b – screw jack acting as a support, 6 – spiral reinforcement # 4.5 mm made of austenitic steel in bed joints installed after removing the wall deflection.
Figure 12. Northern longitudinal wall of the barrack: a) the wall and the steel construction built nearby during rectification, b) the wall after the completed rectification, stabilisation in the new position and dismounting the steel construction.

6. Conclusions
Walls which are largely vertically deformed or deflected are usually repaired by disassembly, and then rebuilding in the vertical position. Such an approach was not possible on the site of the former KL Auschwitz II - Birkenau. The barrack is a historical monument and a historical document, and such a great interference in its structure is impossible. The ethical and conservatory standards applicable at the Auschwitz - Birkenau Museum serve to protect the original substance of all chronological layers of the Museum's objects. This applies both, to the museum collections, archives, as well as to objects such as buildings, ruins, ditch culverts and all other remnants of the former German Nazi Concentration and Extermination Camp. Such conservatory practice limits, the possibility of interference in the historical structure of objects only to technically justified cases of threats to the stability and durability of buildings, after eliminating all other available technical means. Wall reconstruction would signify that its value, as a document, is destroyed. It was decided to rectify such walls; however, the manner of conducting the rectification and the nature of such activity were different in each case.

For the deformed eastern gable wall, rectification consisted of changing the static scheme of the wall. Hinge regions were created in the selected bed joints of the wall. Rigid wall patches were formed by acting on the wall with horizontal forces between the hinge regions. Horizontal forces were equilibrated by constructing a retaining construction outside the building. The wall was then brought to the intended position by forcing the displacement of the wall patches and their relative rotation in the hinge regions. The last measure applied was to stabilise the walls by anchoring with spiral rods made of austenitic steel. The wall was connected with the longitudinal walls and a pillar using a reinforced concrete core. The bed joints after the completed operation were filled with suitable mortar.

For the deflected, outer, longitudinal northern wall, its rotation was forced in relation to the foundation. This was achieved by applying horizontal forces to the wall, offset by the retaining construction built outside the building. After the completed operation, the bed joints in which the rotation took place were filled with mortar.

The described approach, used for deformed and deflected walls is different from the traditional one, but the desired outcome was achieved, of compensating the deformations and ensuring safe operation of the structure for the next decades.

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