Installing an automatic overhead crane in complex conditions

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Summary

Installation issues of an automatic overhead crane on a partially renovated industrial building of a cement plant are presented. Due to particular soil conditions as well as structural inhomogeneities dictated by production requirements, mechanical, structural and also geotechnical aspects had to be carefully considered in a close cooperation among different engineering competences.

Keywords

cranes, industrial buildings, cement plants

Theme

problems and solutions

Introduction

Structural details are often left behind in preliminary design phases even in very important projects such as industrial plants. Of course, in such challenging projects, process aspects and related equipment selection normally play a most important role within the overall amount of works, both under technical and financial points of view. The worth of civil works within an investment in an industrial plant development usually represents a percentage varying in between 10-15% as in power production plants, and no more than 25-30% as in cement facilities or similar plants.

However, it is often realized that a careful assessment of special details at the very beginning of the design could have prevented serious problems during construction and equipment installation stages. Sometimes, the support of civil and even geotechnical engineers to the process engineers during the early stages of a plant arrangement may be very valuable, as occurred in the job that will presented in the following.

In this respect, this short technical note briefly outlines a case history of a quite complex installation of a new automatic overhead crane that had to work properly running on very different supporting structures.

Normally, rail deformability, which is usually the most relevant aspect to be considered in crane rail design, is only assessed limited to "local" supporting structures, i.e. the rail beams. However, in some cases, like the one discussed here, the overall structural behaviour is so inhomogeneous, basically due to very different foundation rigidities, that the rail deformations have to be considered from a much more general point of view. Some unusual rail arrangements, such the one that will be described hereafter, must be considered, accordingly.

Problem description

Within the revamping of the Capitol Cement Plant, (Martinsburg, WV, USA), owned by Essroc, a company of the Italcementi Group, a new storage hall was foreseen, as a continuation of an existing hall.

Most of the existing hall consists of an open steel frame , with 33' (10 m) high steel columns stemming from longitudinal concrete retaining walls, 48' high (14.4 m) (Figure 1, left). The balance of the hall is supported by longer steel columns, extending down to grade (Figure 1, right). Transverse dimension is

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about 84’ (25.5 m); main portal frames are provided at 21’ (6.40 m), while the overall hall length exceeded 600’ (180 m). A crane was working in this storage area, running over 21’ long rail beams. This department was originally used to store limestone.

Figure 1: existing building

The foundations are quite different among different bays, due to progressive building extensions in the past decades. Basically shallow foundations are provided, however.

Two hundred and thirty feet (70.1 m) of this building were demolished and a new plant department was designed, including a storage area for coal and petcoke and a feeding system for clinker production. The new part was designed to exactly match the existing building width and, of course, share the same, new, overhead crane with the remaining existing bays. Main crane data summarized in next table.

Rated Capacity (grab+material)	55000 lb	(245 kN)
Bridge Weight	169400 lb	(754 kN)
Trolley + Bucket Weight	60000 lb	(267 kN)

Table 1: relevant crane data

Due to the requested arrangement of the new hall for process purposes, a monolithic concrete structure was almost mandatory, for the lowest 63’ (19 m) part, while a light steel framed roof was used above, to provide a continuous appearance with the residual existing part.

The overall building design was basically completed by the Process Department of CTG, the engineering company of Italcementi Group, aiming at optimizing the plant layout with respect to plant overall efficiency and to existing facilities to be incorporated into the new production line.

Design issues

While most of the structural issues had been solved at the very beginning stages of the plant design, due to tight cooperation between process and civil engineering departments at CTG, some aspects were highlighted only later, when many parts of the plant were already under detailed design or, even, under construction. For the storage hall department, local soil investigation revealed very complex and difficult soil conditions under the new part, even in the light of the well known soil conditions in the plant area, represented by an almost normally consolidated clay layer over a very discontinuous calcareous bedrock.

It was shown that the clay thickness, in that area, is highly irregular and that the rock outcrop may be actually described as a sudden varying sequence of sharp pinnacles. After a very long debate, pile foundation (Figure 2, left) for the new building was deemed by local soil engineers to be the most appropriate solution.

In this respect, foundation movements in the existing hall, due to subsequent material loading and removal operations, may exceed nearly two inches (50 mm), even if subsequent loading/reloading cycles could overconsolidate the foundation clay. On the other hand, the anticipated settlements for the new hall were limited to less than half inch (12 mm) due to permanent loads and almost zero for possible live or accidental loads.

Figure 2: new building during various construction stages: piling (left), roof erection (right)

Therefore at the interface between the existing and the new part (Figure 2, right), very different structures existed, in terms of both lateral and vertical stiffness.

To summarize the problem, possible differential deformations to be dealt with are roughly outlined in Figure 3, in which the expected deflections are depicted by an exaggerated scale.

As already mentioned, vertical settlement **Δw** of the existing part was assumed to be about 2 in (50 mm); transverse lateral deflection **Δu** at rail level (Figure 3, b), due to both foundation rotation and wall deflection was assessed by means of both structural calculations and field measures. **Δu** = 40 mm was assumed as design parameter.

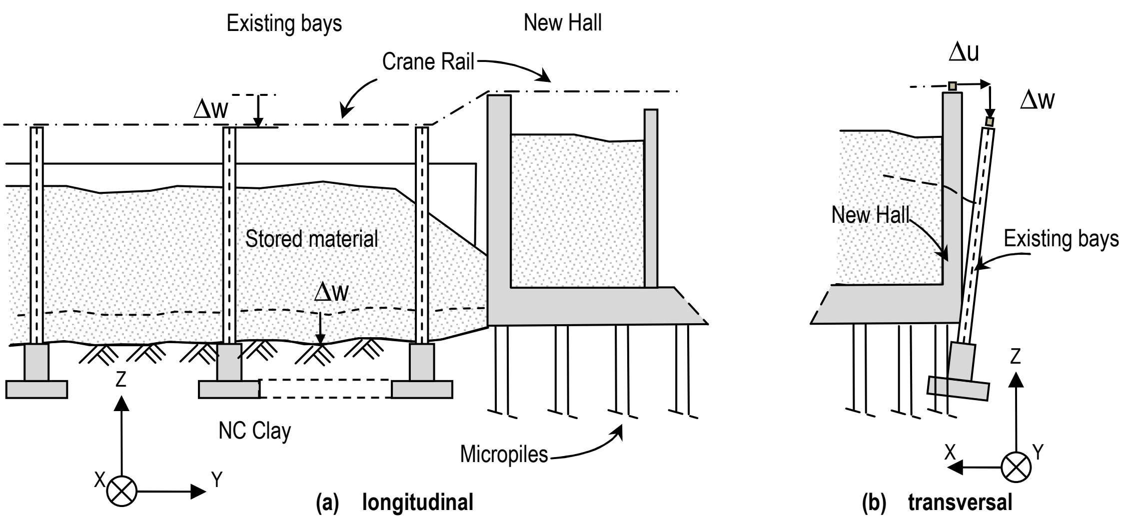

Figure 3: expected relative movements

This aspect was promptly recognized as a very serious issue to be solved if a continuous and seamless transit of the unique automatic overhead crane serving both parts was to be possible.

Proposed solution

Early in the design stages, a survey of the existing building behaviour was performed, thanks to the fact that the loading and unloading operations in that area had not been stopped, even beyond the new building construction start. From this survey, reliable figures for **Δu** and **Δw** could been determined.

To minimize the stiffness differences between existing and new foundation, foundation improvement for the existing columns and walls nearest to the new building was considered. However, it was argued that such a remedy would just shift the problem farther from the interface with the new building towards another position along the existing residual bays. It should be noted, in this respect, that the existing crane apparently had shown no relevant problems working within the original bays. By the way, it should be noted once again that the complete demolition of the overall building had been considered unfeasible due to both financial and, above all, production issues, because the existing plant had to operate as well during all the construction phases of the revamping works.

Thanks to the close cooperation of the automatic crane Manufacturer (Meloni S.p.A.), some remedies were assessed, aiming at preserving, as much as possible, the original crane efficiency, so as not to reduce the design speed and revise the working operations of the crane.

A final solution was proposed, considering that the crane design already had to include some allowance for possible misalignments of the rail beams on the existing supports. This issue was essentially independent from the problem represented by the transition between old and new building. Meloni designed special trolley wheels for the crane, accordingly.

It was therefore concluded that the severe discontinuities had to be smoothed as much as possible by using a special rail arrangement in a limited part around the transition zone.

Keeping in mind that the most problematic deformations for crane performances are, above all, sudden slope changes or concentrated rotations, the remedial solution should be to move crane support on the existing (deformable) structure as far as possible from the new (rigid) building support.

The final solution was found which met the above criteria and, at the same time, did not excessively increase crane loads on the existing columns. The final solution is represented by the installation of the rail over a transition girder, spanning between the new building and the existing column 44 ft (13.41 m) far from the new wall (Figure 4).

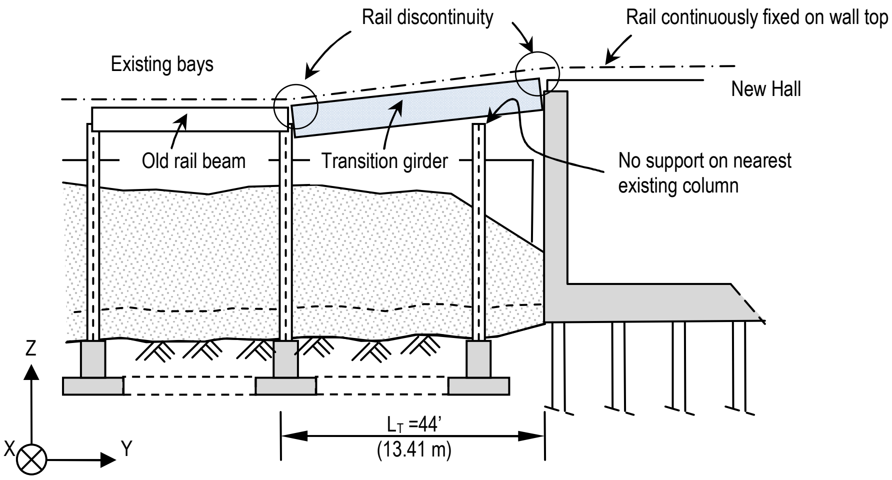

Figure 4: conceptual scheme for remedial solution

This way, concentrated rail rotations in vertical Y-Z plane (θ_x) and horizontal X-Y plane (θ_z) at the transition girder edges are

$$\theta_x = \frac{\Delta w}{L_T}; \qquad \theta_z = \frac{\Delta u}{L_T}$$

With the assumed deflections, we obtain

$$\theta_x = \frac{(50\text{mm})}{(44\text{ft})(12)(25.4\text{mm})}\times 100 < 0.4\%; \qquad \theta_z = \frac{(40\text{mm})}{(44\text{ft})(12)(25.4\text{mm})}\times 100 < 0.3\%$$

Such concentrated rotations were deemed allowable as far as crane performances are considered.
Moreover, at the end of the erection of the new building, a complete topographic survey revealed a significant geometric misalignment of the theoretical crane rail lines over the new part, with respect to the projection of the existing lines from old parts.
Such unexpected issue could be corrected as well, by simply increasing the rotation capabilities of the transition system, i.e. improving the rotation allowance at the transition girder edges, in the horizontal plane.
As for the structural aspects of the transition girders, special attention has been put in the definition of the support details on both existing and new structures. Such supports had to permit the abovementioned rotations and, at the same time, to carry the design loads due to crane working conditions.

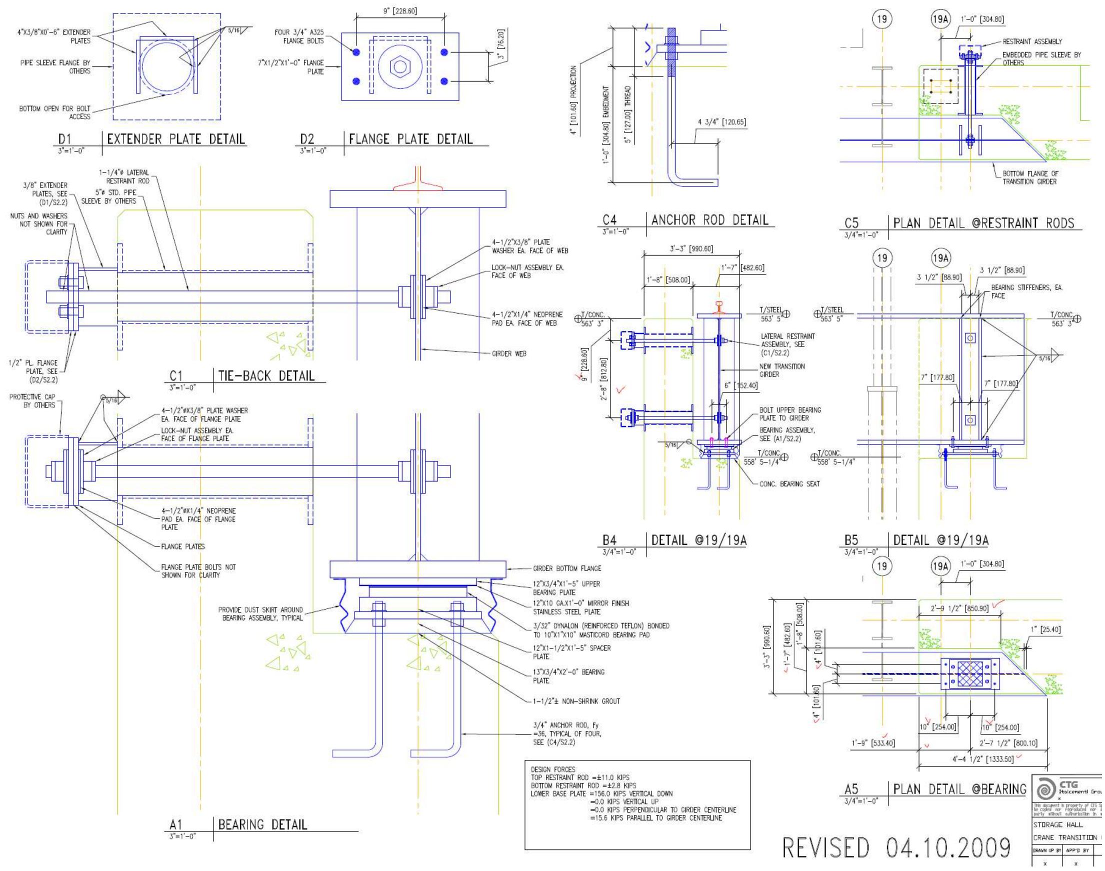

Figure 5: connection detail on new (rigid) part

While the design of the transition girders could be performed in accordance to usual design criteria [1], special care had to be reserved for support detailing over both existing and new structures. Moreover, the crane rail itself had to be subdivided properly, in order to allow relative movements and rotations at both edges of the transition zone.

In Figure 5 the structural detail of the support on the new part (concrete wall) is outlined. Notice that vertical rotation is basically ensured by simply providing a sliding bearing pad the bottom flange of the transition girder. Notice also that in very polluted environments such as in a cement plant, much attention should be put in preventing support seizure by dust: in this case, the installation of a flexible protection skirt was recommended (see Figure 5, det A1).
Lateral restraint is provided by two special steel arms (tie-backs, in Figure 5) connecting the girder at both flanges to the concrete wall. In order to allow as much movement as possible in longitudinal direction, as well as rotation about vertical axis, the tie-back length was set as long as allowed by local geometry.
Tie-back rotation capability in horizontal plane was also improved by providing neoprene pads between washers and connecting plates, at both ends (see Figure 5, det C1).

In Figure 6, the connection detail on the existing steel column is outlined. Essentially, same design philosophy was adopted as in the other detail. We also notice that the longitudinal restraint for the transition beam is provided at this edge, in order to withstand braking crane actions.

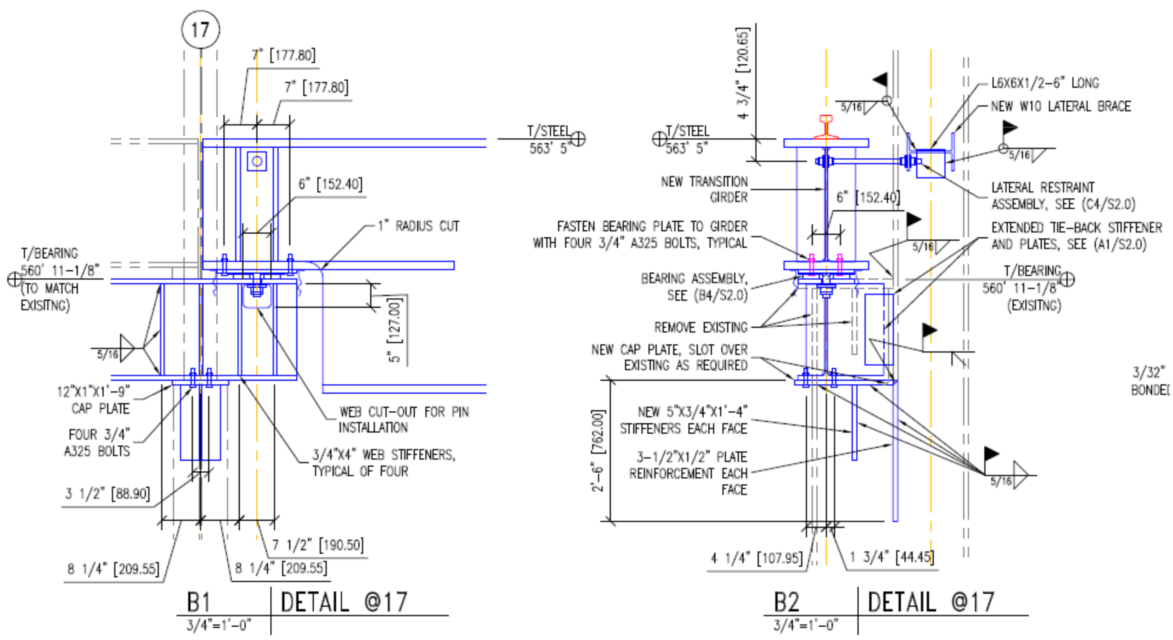

Figure 6: connection detail on existing (deformable) frame

As for the remaining existing halls, original rail girders have been carefully reviewed and accepted for new loadings as well.

In Figure 7, the rail detail at each transition girder is shown. This arrangement was carefully studied by MELONI. While it is usually recommended to provide continuous rails over all the crane working area, in this case, of course, discontinuities were mandatory: the main consequence from this unusual rail arrangement is just the need of ensuring a reduced speed in the limited transition zone.

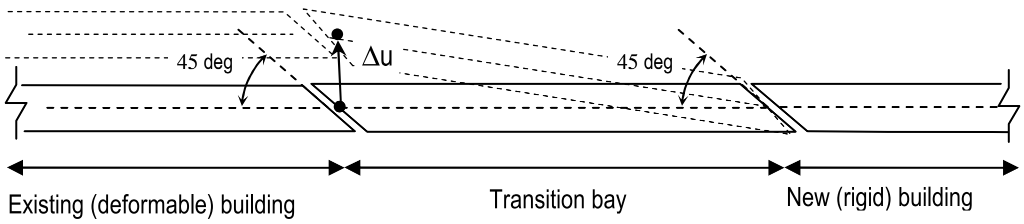

Figure 7: rail discontinuity detail (top view)

A posteriori assessment of the proposed solution

On our best knowledge, the crane has been working properly for more than one year. Neither wheel or rail wearing nor other malfunction clues, such as excessive noise, have been reported, at the moment.

In this respect, it is important to remark that the selection of an automatic crane rather than a manually driven crane may improve overall effectiveness and reliability under structural point of view as well, in cases like this: in fact slightly reduced crane speed over the transition area is ensured, in this case, by simply reprogramming the crane driving computer, rather than relying on a careful compliance with an operating procedure by the personnel on the Plant.

In Figure 8 a very recent picture of the transition beam at the support on the new building is shown. Heavy dust deposition is very evident. Nevertheless, the crane rail is essentially dust-free, thus witnessing that the automatic crane transit is a routine event even in this special bay of the hall.

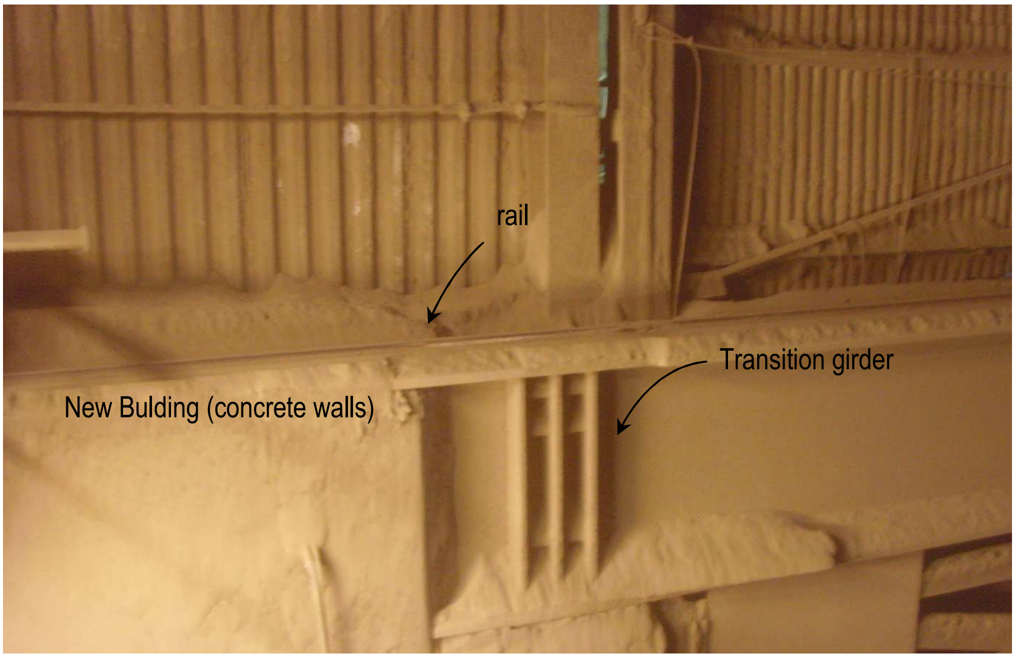

Figure 8: transition area near to new part

Conclusions

The installation of an automatic crane is usually treated as a detail issue within the structural design of an industrial building. In a renovation project, however, the renewal of such equipment may deal with very inhomogeneous deformability of the supporting structures. In such cases, a careful assessment of all mechanical, structural and geotechnical aspects should be performed through a close coordination between all the engineering departments involved in plant design. As long as the structural complexities increase, multidisciplinary design may become a necessary requirement even in ordinary projects.

References

[1] AISC - American Institute of Steel Construction, *Steel Construction Manual*, 13th ed., 2005

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