Damage to the Vertical Braces of Industrial Buildings

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Abstract. The article describes the types of vertical connections of industrial buildings, presents the results of surveys, describes typical defects: bends of the connecting grid, cutouts of elements, local bends and curvature of branches of connections, destruction of attachment points. The description of unique damages of vertical connections is given: cut branches of connections, fastening of connections to crane beams, change of the design decision of connection. In conclusion, the analysis of zones of formation of defects and grouping of defects by zones of formation is performed.

1. Introduction
This article is a continuation of the articles’ series by the authors on defects and damages of industrial buildings, earlier the industrial buildings’ bases [1, 2], foundations [3, 4], facades [5–8], columns (in print) defects analysis had been performed [9, 10]. The article describes typical defects and damages of vertical stiffness braces, the main reasons for their formation as well as recommendations for eliminating the detected defects and damages. Unique damages’ descriptions to vertical braces and design errors during reinforcement work are also given. The authors have analyzed the characteristic zones of defects and damage formation, their grouping.

In recent years, the technical condition of industrial buildings built in the 1960s and 1980s has noticeably deteriorated due to the expiration of the standard period of their operation. Owners of industrial enterprises, who want to know the technical condition of the building and possible expenses for repairs, are increasingly attracting qualified specialists-builders of the SRSPU (NPI) to inspect the production building and develop recommendations for bringing it into a working technical condition.

2. Problem statement
Vertical stiffening braces are an integral part of any industrial building and provide the spatial rigidity of the building’s reinforced concrete frame as a whole. The design solutions analysis revealed the following vertical stiffness braces: cruciform (X-shaped), portal, V-shaped and even cruciform with a horizontal spacer. Cruciform braces are more often placed in buildings with a column pitch of 6 and 12 m and along the extreme row of columns, portal braces are more often placed in the central rows with a column pitch of 18 and 24 m, so that equipment can be installed between the columns. The braces can also be made of metal standard sections or paired channels, while the sections can be paired, and the branches from the channels can have a connecting grid. V-shaped stiffness braces are often installed as the second tier in the above-crane column zone.

To ensure the presentation of the results of the survey of industrial buildings in machine-readable form and their integration as a module of an automated system, it is necessary to improve the
methodology and, by analogy with the survey of other load-bearing structures of buildings and
structures, it is necessary to systematize defects by causes and their impact on the remaining resource
of the building with the Union in the enlarged zone.

3. Research result
The most common damage to vertical stiffness braces is the connecting grid deflection (Fig. 1, a) as
a result of mechanical damage. The reasons for the deflections emerging are transport impacts: a car
during loading or unloading, a truck during maneuvers, an overhead crane when moving goods, etc.
The technical condition of vertical links with such damage is, as a rule, of limited working capacity.
Since such damages have a random and single occurrence nature, they do not develop in the absence
of repeated exposure to transport load. This damage is eliminated by straightening the damaged
element, or, most often, by replacing the damaged element with a section or channel.

The connecting grid elements’ cutouts are no longer accidental damage, since the causes of their
occurrence are the actions of the personnel operating the industrial building (Figure 5.4). Most often,
workers cut out a service line element when it is necessary to lay communication lines, if it is
necessary to install equipment, etc. These cuts lead to the vertical connection disruption, change its
rigidity and strength, which can lead to the columns’ deflections from the vertical and change the
building rigidity. The technical state of vertical braces with cutouts is of limited serviceability. This
damage can be eliminated by restoring the cutout elements by electric welding.

Local branch deflections are also one of the most common damage to vertical braces. The
deflection causes are mechanical damage by transport - strikes by trucks and autocars. Such damage
leads to a local weakening of the vertical connection and to the disruption of its normal operation, in
the future such a defect can lead to a distortion of the power load connection. The technical condition
of the damaged connections is assessed as partially functional. Damage is eliminated by straightening
the element on the damaged area, followed by reinforcement of steel plate welding 100 mm more to
one side and the other from the damaged area. After alignment and strengthening, it is necessary to
paint the metal structures with anti-corrosion compounds.

Curvature of braces branches. A much less common defect is the curvature of the branch of the
vertical stiffness brace (Fig. 1, b). This damage occurs most often in open or covered, freestanding
crane racks or transport galleries. The reasons for these defects emerging are the dynamic impacts by
transport, road or rail. However, in some cases, curvatures are possible precisely from the force factors
due to the foundations’ subsidence of one of the columns, or the column deflection from the vertical.
This damage leads to the vertical brace disruption, a change in the design scheme. The technical state of the braces with such damage is unacceptable or not operational. This damage is
eliminated by straightening this brace with subsequent strengthening, or replacing the elements of the
vertical brace with the similar ones that do not worsen its characteristics.

Destruction of attachment points - in some cases, vertical stiffness braces are not established
during the building construction, but due to various needs during the building operation. Such reasons
may be significant vibrations of one of the columns, or the column foundation settlement, or there may
be a deflection from the vertical of the column. These connections are performed by framing the
columns with metal connection clips, to which the brace structure is welded. The authors have
repeatedly noted damage to the welds of the connection clips. This defect leads to the vertical stiffness
brace disruption, in fact, the attachment point is destroyed, and the vertical brace is out of the
operation. The technical condition of such a brace is not operational; it is necessary to restore the
attachment point using electric welding and re-paint it with anti-corrosion compounds to eliminate it.
Vertical stiffening braces sometimes have damage in the form of a partially cut branch, or a completely cut section of the stiffening brace (Fig. 2). These damages are rare, and the reasons for their occurrence are always the working personnel operating the industrial building. The branch of the vertical brace is cut to accommodate the technological equipment, while the vertical brace does not provide the specified rigidity of the industrial building frame. The technical state of such a vertical stiffness connection is assessed as partially workable or unacceptable. The detected damage is eliminated by restoring the vertical stiffness brace according to a specially developed project; it is possible to replace the stiffness brace from a cruciform brace to a portal one, depending on technical conditions. In case it is impossible to restore the vertical brace at a given column pitch due to technological equipment, then it is necessary to consider the options for installing a vertical stiffness brace in an adjacent column spacing, where it is permitted by the design solution.

Damage to the vertical braces in the form of section removal is much less common. Another rare damage is the half portal stiffness brace dismantling. The technical condition of such damaged braces is assessed as inoperative, since the structural brace scheme and the longitudinal stiffness brace of the building are violated. Damage is eliminated by restoring the vertical brace according to the specially developed project. Cases of completely dismantled vertical stiffeners are very rare. At the same time, the nodes for attaching braces to the columns remain, according to which the fact of its dismantling is determined. Such damage is assessed as unacceptable and requires restoration according to the specially developed project.
A unique case of the damage was revealed during the industrial building inspection of the metallurgical plant foundry in Belaya Kalitva. Vertical stiffening braces were made not in one column spacing, as customary, but in two different, but tied to one column (Fig. 3). In this case, the error in the vertical braces’ implementation lies in the connection with the crane girder. The reason for such damage emerging could be the technological necessity of placing the equipment in the place where the vertical stiffness brace is installed. The portal brace was cut and the sheared part was installed in the next columns’ spacing, while the horizontal strut was sheared, and the brace branches had to be fixed to the crane beams. This technical solution completely excludes the vertical stiffness brace from work and disrupts the crane beams operation. The technical state of the vertical stiffness brace should be assessed as unacceptable, and the crane girders as limited serviceable. This damage is eliminated by restoring the vertical brace to the design position according to the specially developed project.
Figure 3. Fastening the vertical braces to the crane girders.

Another unique case was revealed during a survey of an industrial building in Rostov-on-Don. The vertical brace has been redesigned to accommodate between the columns of the rail track for the trolley (Fig. 4). One V-shaped brace branch was cut and replaced with a portal brace branch. With such a technological solution, the communication efficiency is not disturbed, the structural rigidity of the building is ensured.

When inspecting industrial buildings, it is possible to face the technical need to dismantle the cross-shaped vertical stiffness brace, since it interferes with the technological equipment placement, while the way out of this situation can be replacing the cruciform brace with a portal brace or transferring the brace to another column row.

Figure 4. Constructive changes in vertical links.
4. Conclusions
Violation of the vertical rigidity links leads to loss of stability of the production building and violation of its spatial rigidity. After analyzing the above presented material, the authors propose to identify the following formation zones of defects and damage to vertical braces:

**Zone 1** – damage to the connecting grid elements. This group will include local bends of the connecting grid, violations of the cross-section profile of the element, cutouts of the elements of the connecting grid.

**Zone 2** – damage to the brace branch cross-section (deflections). This group will include local bends in the cross-section of the link branches, and curvature of the link branches.

**Zone 3** – brace branches curvature (branch deflections). This group includes the destruction of welds of fastening units, corrosion of fastening elements, and the loss of fastening elements.

**Zone 4** – vertical braces’ attachment points destruction. The last group includes damages related to cutouts of individual branches of the link, a complete cutout of the vertical link, and changes in its spatial scheme.

**Zone 5** – brace branches or brace sections cutouts.

This zoning allows you to develop a new program for automating the process of inspection of industrial buildings and subsequent monitoring of the development of identified defects and damages, as well as to monitor the technical condition of the industrial building and track the dynamics of negative processes and timely carry out major repairs of the building.

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