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Local seismic load on the column of industrial building

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Abstract. When determining the standard seismic load on a single-stored industrial building, the calculation model may vary depending on the task and the structural and technological characteristics of the building. In most cases, a single-mass cantilever model is accepted, providing sufficient accuracy in determining the system's operation. This paper proposes a method for determining the local seismic load on the column of a one-stored industrial building from a top running overhead crane. The method takes into account the location of the crane relative to the column during an earthquake and, accordingly, the way this load is applied to the column.

Keywords: Dynamic model; Seismic load; Top running overhead crane.

Introduction

One of the most significant loads for single-stored industrial buildings comes from the vertical and horizontal forces transferred by top running overhead crane [1,2]. During a seismic event, the nature and value of the crane's impact change. When calculating the framework of a single-stored industrial building for seismic resistance according to standard methodologies [3,4,5,6], horizontal seismic loads from crane equipment are taken into account. However, there are no clear requirements for the dynamic model of the top running overhead crane-bearing structure [7,8]. Generally, the method of accounting for the horizontal seismic load from the weight of the top running overhead crane depends on the design model of the framework.

Main Part

When using a dynamic model in the form of a cantilever with mass concentrated at the top of the columns (a system with one degree of freedom), the forces caused by the local seismic load in the transverse direction from the crane bridge girders' own weight must be considered for columns carrying the crane load.

The calculation model proposed for this case [9,10] is represented as a rigidly embedded column with a concentrated mass at the bottom of the runway beam and a fixed upper end (Fig.1). The value of the concentrated load is assumed to be equal to the maximum pressure on the column from the crane bridge girders' own weight, taking into account factors of overload and load combination. For multi-span frameworks within the column spacing, one crane is accepted in each span, with the bridge girer located over the column such that one wheel is coaxial with the axis of the examined column. The dynamic factor (β) is taken at its maximum value, in accordance with the seismicity category of the soil.

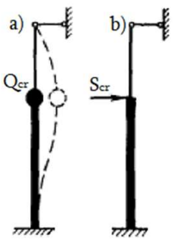

Fig. 1. Schemes for calculation of the column on local crane load
a) dynamic calculation model,
b) action of quasi-static seismic load on the column.

Crane load is a moving load whose probability of being at any particular point during an earthquake is practically zero. The value of the standard local seismic load on a column depends on the relationship between the size and inertia characteristics of the top running overhead crane and the supporting structures, the location of the crane during the earthquake, and consequently, the method of applying the load to the column. These indicators can be taken into account using the calculation model presented in this article (Fig. 2). It is based on representing the top running overhead crane mass not as concentrated on the column axis at the bottom of the runway beam, but as connected to the column at this point by a transversely yielding constraint. This approach accounts for the ductility/rigidity of the examined column and runway beams in the transverse direction, respectively the position of the crane and the method of load transfer.

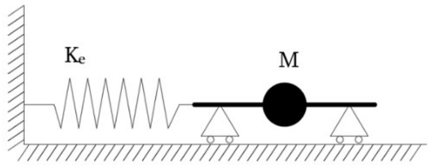

Fig. 2. Dynamic calculation model of top running overhead crane - column for determination of local seismic loading

The value of the concentrated mass (M Fig.2) is determined by the maximum value of the crane wheel load [11] and accordingly the pressure influence line, considering two adjacent column spaces to the examined column. The stiffness of the constraint k_e is equal to the equivalent stiffness of the sequence connected constraints (springs) modeling the column (k_1) and crane beam (k_2) in the transverse direction [13]:

$$k_e = \frac{k_1 k_2}{k_1 + k_2} \tag{1}$$

Considering the top running overhead crane as an absolutely rigid body (bridge girders + end trucks), the value of k_2 corresponding the reaction to a unit displacement in the direction of the bridge girder, nearest to the examined column.

The period will be equal to:

$$T = 2\pi \sqrt{\frac{Q}{g \cdot K_e}} \tag{2}$$

Based on this model, we will consider a specific problem: determining the local seismic load on a column of a one-stored, single-span industrial building (Fig. 3) with a top running overhead crane with a load capacity of 12.5t [11], constant cross-section columns [12], and a discontinuous scheme of runway beams (cross-section with a developed top flange, without a braking force transferring girder [2]).

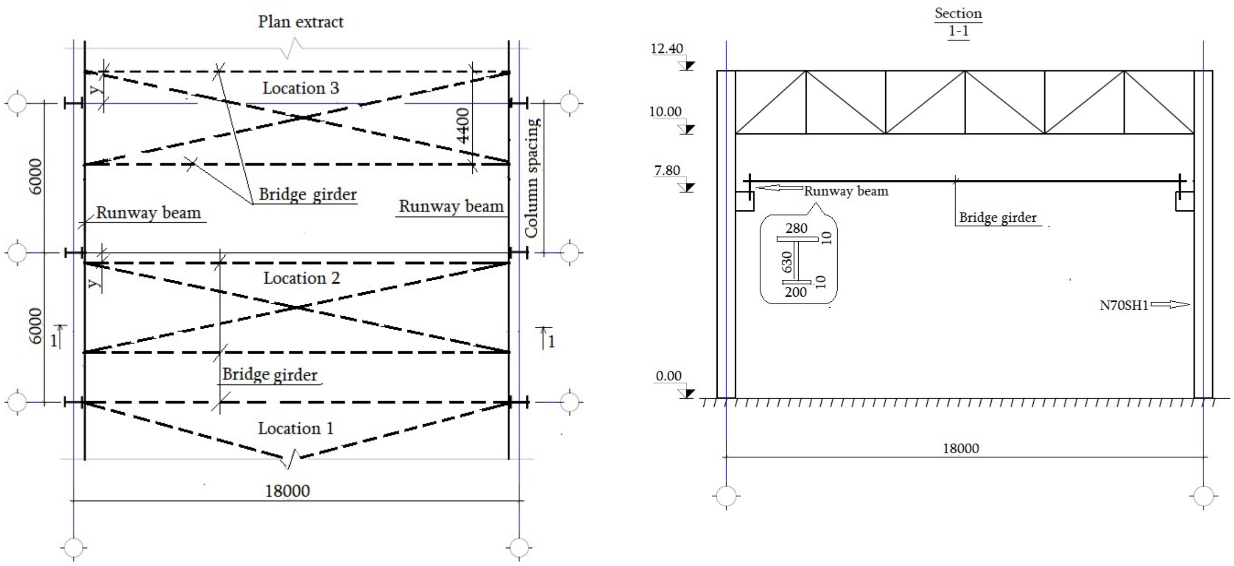

Fig.3 Calculated one-stored single-span industrial building

At determining the local seismic effect on a column, the location of one double-girder top running overhead crane in relation to the examined column may be:

a) one wheel of the crane is coaxial with the axis of the examined column (Fig.3 Location 1);
b) the crane is entirely in one column spacing with a smaller distance to the examined column (Fig.3 Location 2);
c) in two adjacent column spacing with different or equal distance to the examined column (Fig.3 Location 3).

The results of the calculation are summarized in Table 1. As can be seen from the table, for one particular case the values of the dynamic factors in sporadic cases are in a lot lower than its maximum standard value. Taking into account the variety of structural solutions of buildings and types of cranes and their operating modes, we consider it necessary to determine the dynamic factor according to the conditions of each specific task.

Table 1

Results of the calculation

Location of crane (m) Fig.1	Load (kN)	Rigidity (n/m)			Period (rad/s)	Dynamic factor (β)		
		k_1	k_2	k_e		I	II	III
L1	160,0	$58 \cdot 10^6$	------	$58{,}00 \cdot 10^6$	0,10	2.5	2.5	2.5
L2 y=0,5	138,6	$58 \cdot 10^6$	$12{,}50 \cdot 10^6$	$10{,}28 \cdot 10^6$	0,23	2.5	2.5	2.5
L2 y=0,8	126,0	$58 \cdot 10^6$	$5{,}26 \cdot 10^6$	$4{,}82 \cdot 10^6$	0,31	2.5	2.5	2.5
L3 y=1,5	160,0	$58 \cdot 10^6$	$2{,}10 \cdot 10^6$	$2{,}03 \cdot 10^6$	0,56	1,9	2,5	2.5
L3 y=2,2	160,0	$58 \cdot 10^6$	$1{,}35 \cdot 10^6$	$1{,}32 \cdot 10^6$	0,69	1,7	2,2	2.5

Conclusion

Types of top running overhead cranes and its supporting structures - elements of one-stored industrial building are characterized by great constructive and technological diversity. This diversity requires a calculation for each specific case, the basis for which can serve as a proposed model with adjustments appropriate to specific conditions.

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