Materials Science Forum
ISSN: 1662-9752, Vol. 968, pp 348-354
doi:10.4028/www.scientific.net/MSF.968.348

Submitted: 2019-03-29
Accepted: 2019-05-29
Online: 2019-08-23

Features of the Design of Steel Frame Structures in India for Seismic Areas

BANNIKOV Dmytro Olegovitch[1,a*], RADKEVICH Anatoliy Valentinovitch[2,b]
NIKIFOROVA Nataliya Anatoliivna[3,c]

[1]Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Department of Construction Production and Geodesy
Lazaryan str., 2, Dnipro, Ukraine, 49010

[2]Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Department of Construction Production and Geodesy
Lazaryan str., 2, Dnipro, Ukraine, 49010

[3]Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Department of Construction Production and Geodesy
Lazaryan str., 2, Dnipro, Ukraine, 49010

[a]bdo2010@rambler.ru, [b]anatolij.radkevich@gmail.com, [c]2017natanik@gmail.com

Keywords: Frame Structures, Seismic Design, India, Seismic Standards, Finite Element Method, SCAD Software

Abstract. This article is devoted to the analysis of one of the most common structural designs of the steel frame of small spans, currently used in India in construction and reconstruction for seismic areas. This scheme constructively involves the implementation of the main bearing elements - bolts and columns - in the form of a spatial truss box section. At the same time, rather simple rolling profiles from small-sized corners are used, as well as a round steel bar.
The studies performed by the authors were carried out using the finite element method based on the national design computing complex SCAD for Windows. The loads, as well as the geometrical characteristics of the profiles, were taken according to the current building standards of India. Based on the results of the analysis, a number of recommendations were formulated to improve the efficiency of the considered design scheme for seismic effects of varying intensity.

Introduction

Currently Ukraine actively develops cooperation between various private companies and enterprises in India and Ukraine. This is particularly evident in the pharmaceutical field, associated with the production of inexpensive medicines and drugs that can be sold without special prescriptions and are intended for domestic use (such as the well-known Strepsils throat lozenges and their analogues). Their manufacture requires special small plants, which in terms of labor and raw materials are much more profitable to locate in India.

Such mini-plants are very often created on the basis of existing buildings, often not used for various reasons. At the same time, special redevelopment and reconstruction of these objects is carried out, often with a superstructure of 1-2 additional floors to accommodate specialized equipment. Also quite common is the option of construction a new building, originally intended for a specific pharmaceutical production. However, the first option is cheaper and more common in India.

In both cases, these mini-factories to the northern part of India, where now there are more economically acceptable conditions for pharmaceutical production. However, it is the northern part of India, located in the foothills of the Himalayas, is the most seismically unstable. According to the construction standard of India dedicated to the design of building structures in seismic areas [1], it is the northern states that are located in the IV and V seismic zones. They correspond to the magnitude of earthquakes on the MSK-64 scale, adopted as the main one also in the national standard [2], of 8 and 9 points, respectively. Such a high level of seismic hazard requires the use of special design solutions that would resist these impacts.

Analysis of Special Design Solutions

Goal and object of researches. To date, the practice of creating steel frame structures for small buildings in India, capable of withstanding significant seismic effects, has already gained a lot of experience. The most universal and common design solution is the use of spatial lattice truss elements that form the frame system - fig. 1.

a)

b)

Fig. 1. Design solution of a multi-span frame building:
a) extreme knot; b) middle node

Horizontal (bolt) and vertical (column) elements of such a frame are made according to the same type of design scheme. It is a truss of rectangular or square cross-section with overall dimensions up to 400-500 mm. The belts of such a truss are made of single equal-angle corners, which are turned with a feather inside the section. Racks are arranged in increments of 1 m, which allows you to attach to them the horizontal elements of the coating or wall frame. The racks themselves are also made from the corners, turned by a feather inside the farm. The bracing is made in a triangular pattern and is a steel bar of the required length, welded to the inner surfaces of the corners from the corners. In the field of support nodes, the truss can be reinforced with additional plates, which is more often characteristic of vertical columns, or diagonals in the form of corners, which is more often characteristic of horizontal bolts. Profiles for elements are accepted according to the Indian standard for hot-rolled profiles [3].

However, such a constructive scheme is very often used in the practice of creating steel frame structures without any additional theoretical justification, binding to local conditions, based on practical experience rather than theoretical analysis. Therefore, the authors of this article discussed the effectiveness of the work of structural elements with a similar structural scheme, which is the *goal of the performed studies*.

As a *subject for research* , a two-story frame building was chosen, located in the city of Baddi (Himachal Pradesh). To be able to use it as a mini-plant in the pharmacological sphere, the building was subject to reconstruction, which consisted in adding an additional floor and organizing a special attic space. The need for such space is due to the requirements of the current legislation of India in the field of civil engineering and can significantly reduce the cost of obtaining a permit to operate the building.

Structurally, the original building is made in a reinforced concrete frame and has a rectangular shape in plan with dimensions of 21 × 56 m. The frame is formed by a system of transverse frames consisting of vertical columns and horizontal beams. The superstructure is performed on a similar frame system, but with a more rare column pitch - fig. 2.

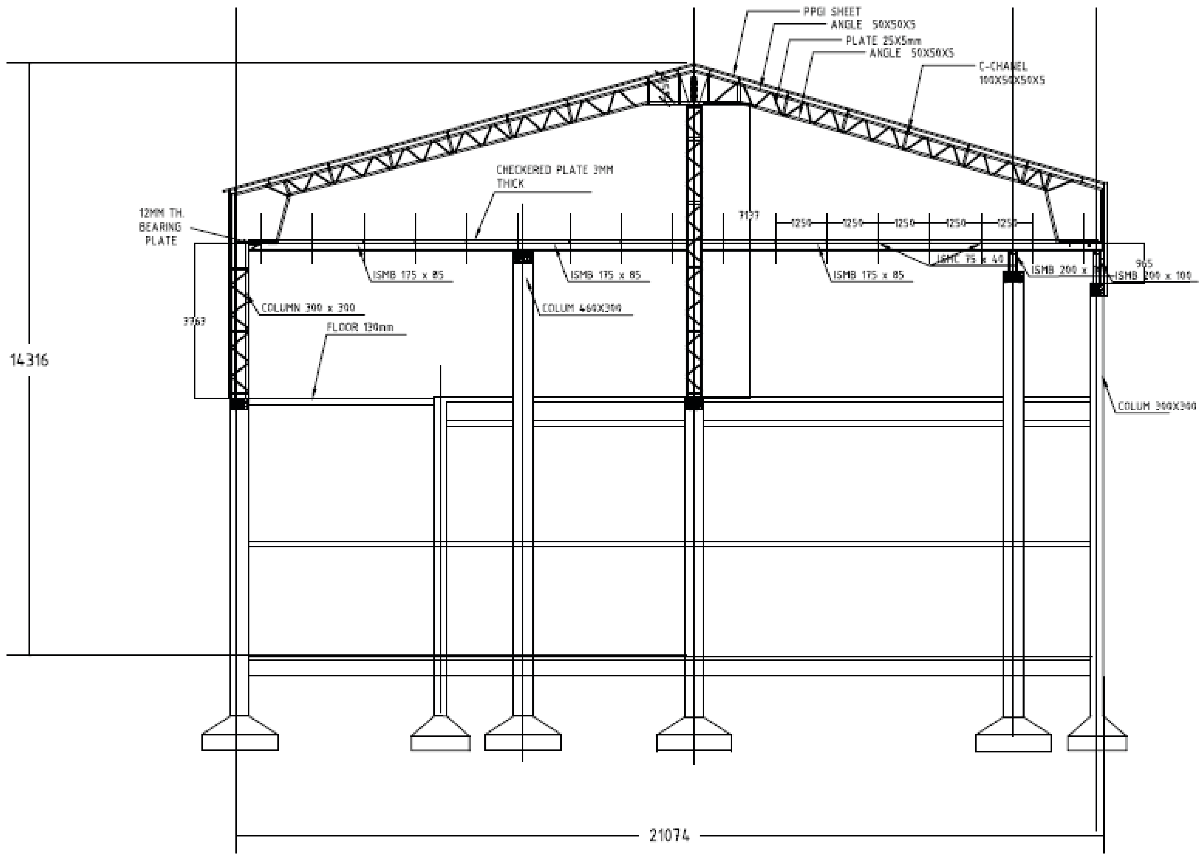


Fig. 2. Transverse frame of the analyzed frame building.

The overlap provides for the installation and location of special technological equipment; therefore, it constructively represents steel flooring laid on a beam cage of I-beams. The coating has a fairly standard design solution, characteristic of unheated buildings and common, also in European countries [4]. It provides for a system of horizontal longitudinal runs of light rolled profiles, on which galvanized profiled flooring is laid. To prevent the ingress of water through the joints into the building, the slope of such a coating, as recommended by domestic standards [5], takes at least 20% (11 °).

All structural elements of the superstructure of the building are made of steel grade S275J2, which has a design resistance of not more than 240 MPa. It should also be noted that the connection elements are assumed both in welding and bolts.

The soils in the area of the reconstructed building are coarse-grained, lying down to a depth of about 10-20 m. In accordance with the accepted classification according to the norms [6], such soils correspond to category II. In combination with the high level of seismic effects, this region of India is rather difficult for design and construction in general.

FEM-analysis of the structure scheme. To evaluate the performance of this structural solution of the steel frame, the well-known numerical method of structural mechanics, the finite element method [7–9], was used on the basis of the domestic design-computing complex SCAD for Windows [10].

The finite element scheme of the steel frame was a core system formed from rod finite elements of a universal type. Its appearance is shown in Fig. 3. Such an approach allowed to avoid questions of evaluating the convergence of the results obtained, which are characteristic of finite elements of other types [11].

As the boundary conditions, a rigid attachment of the elements of the steel frame to the existing elements of the reinforced concrete frame was proposed, which was modeled by prohibiting all degrees of freedom in the corresponding nodes. Also, in addition to the crossbar and the column, the horizontal support beams of the floor and small supporting posts in the right side of the frame's cross-frame structure were included in the design model. They were made of I-beams.

All calculations were carried out in a geometrically and physically linear formulation. The main design load was the seismic load specified by the standard means of the design-computing complex SCAD for Windows. Since the Indian Standard [1] is not in the library of this complex, the calculations were based on the updated edition of the Russian norms [6], on the basis of which the Indian Standard was developed. Another load that was taken into account was the payload on the overlap from people and equipment, specified according to the standard [12].

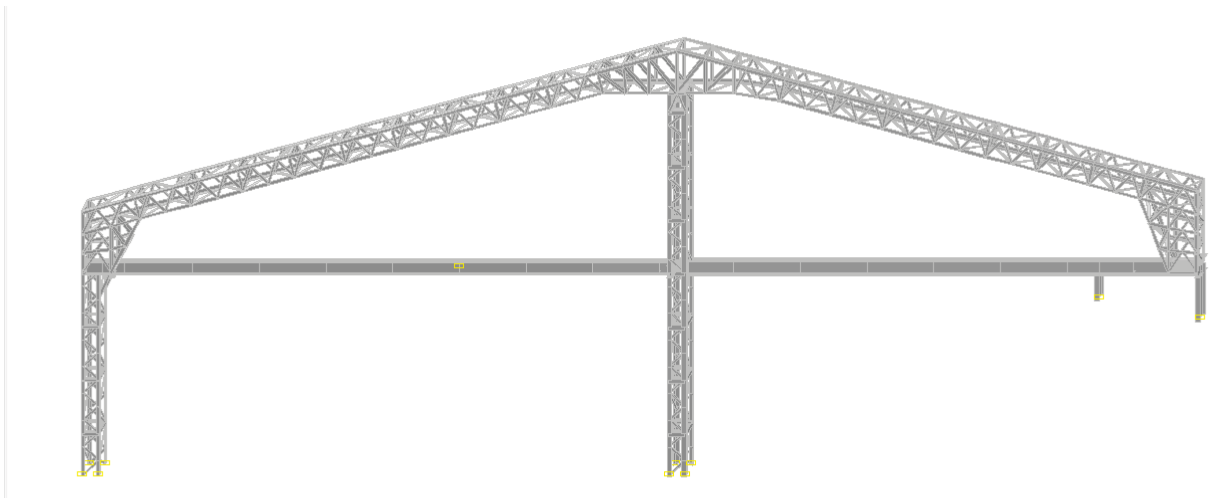
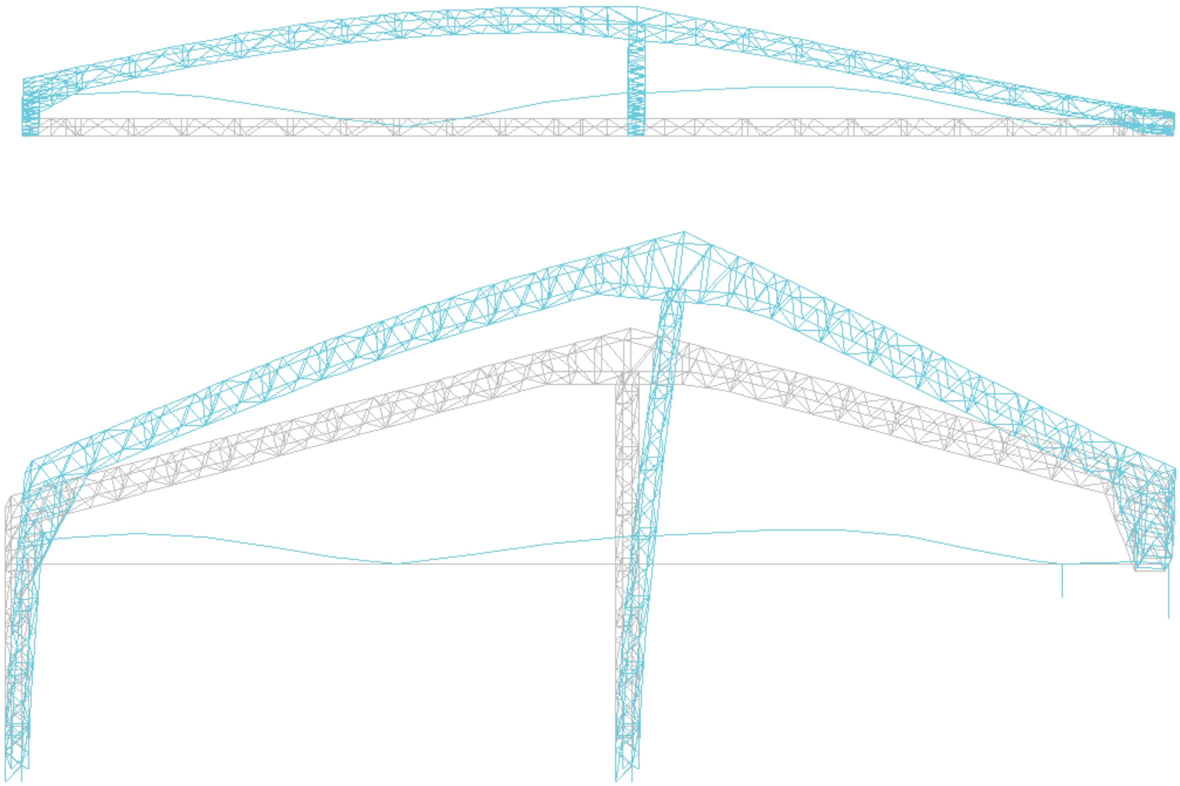


Fig. 3. Finite element diagram of the transverse frame of the frame building being analyzed

In the course of preliminary calculations and analysis of the results obtained, it was found that the box section, adopted for bolts and columns, is a rather effective design solution for seismic effects. Moreover, the degree of its effectiveness, assessed by the nature of the stress-strain state, essentially depends on the presence and stiffness of horizontal connecting elements located in a plane perpendicular to the frame of the carcass. These elements prevent the occurrence of torsional deformations in girders and columns, leading to the occurrence of predominantly linear deformations from the surface of the frame, which is more preferable - fig. 4. Therefore, in comparison with flat girders and columns, traditionally used in domestic practice, the spatial design scheme used in Indian practice is much more rational.



a)

b)

Fig. 4. Deformation of the transverse frame of the analyzed carcass building from seismic effects: a) top view; b) side view

However, this design scheme has certain disadvantages. In particular, the use of steel bars for the trusses of trusses significantly reduces its stress-strain state - table 1 (the numerator shows the values for seismic impact intensity of 8 points on the MSK-64 scale, and in the denominator - 9 points). Therefore, for the perception of seismic effects, especially high intensity of 9 points, it was necessary to use for the diagonals of flat plates 40 mm wide oriented in the plane of the lateral faces of structural elements. In this case, the minimum required for the conditions of local stability is a thickness of 6 mm. Also in Table 1, mass indicators are additionally given for different variants of the structural scheme, which allows to evaluate their effectiveness.

After adjusting the structural design for the crossbar of the transverse frame of the building, it became clear that vertical columns had to be carried out along a similar structural scheme. Moreover, since the transverse frame itself is statically indefinable, further calculations aimed at selecting sections of column elements were carried out according to an iterative scheme. The final sections of the column elements taken as a result of the calculations, as well as indicators of their stress-strain state, are given in Table 2 (the numerator shows the values for seismic impact intensity of 8 points on the MSK-64 scale, and the denominator - 9 points) The arrangement of the columns corresponds to that given on the constructive scheme of the building (Fig. 2).

Table 1 - The stress-strain state (VAT) of the crossbar frame

VAT rate	Cross section (mm)			
	circle 10	plate 5	Plate 6	plate 7
Mises strength (MPa)	284/568	109/217	103/205	92/184
overall stability	0,66	0,58	0,97	1,51
local sustainability	1,26	0,70	1,21	1,93
oscillation amplitude (mm)	93/187	67/133	62/124	60 / 120
Weight (kg)	840	950	1000	1040

Table 2 - The stress-strain state (VAT) of the columns of the transverse frame

VAT rate	Section of the column			
	left ∟50 × 5 / ∟50 × 5	average ∟50 × 5 / ∟80 × 6	intermediate MB 200 / MB 200	right MB 200 / MB 200
Mises strength (MPa)	112/241	196/248	49/92	67/123
oscillation amplitude (mm)	22 / 44	103/146	1 / 1	2 / 2

Additionally, at the request of the customer was analyzed the work of the horizontal beams located in the plane of the supporting frame. The selection of their section was also carried out according to an iterative scheme, as well as for vertical columns. The final sections of the column elements taken as a result of the calculations, as well as indicators of their stress-strain state, are given in Table 3 (the numerator shows the values for seismic impact intensity of 8 points on the MSK-64 scale, and the denominator - 9 points) The location of the ceiling beams corresponds to that shown on the structural design of the building (Fig. 2).

Table 3 - The stress-strain state (VAT) of the beams of the transverse frame

VAT rate	Beam section	
	left MB 175 / MB 225	right MB 225 / MB 250
Mises strength (MPa)	149/171	212/239
oscillation amplitude (mm)	42 / 55	39/61

The total mass of the finally adopted design solution of the transverse frame of the steel frame of the given building was for an option under a seismic load of 8 points - 1900 kg, under a seismic load of 9 points - 2200 kg.

Summary

Thus, on the basis of the performed finite element analysis of one of the most common in India design schemes for the steel frame of small span buildings for seismic regions, the following should be stated:

1. The use of a spatial box-like structural scheme for horizontal girders and vertical columns of the transverse frame under seismic load conditions is quite effective comparing with a flat structural scheme. Moreover, the degree of its effectiveness essentially depends on the presence and

stiffness of horizontal connecting elements located in a plane perpendicular to the frame of the carcass.

2. The use of frame bearing elements as bracing steel bars significantly reduces the performance of their stress-strain state, especially in terms of the overall stability of the structure as a whole. For effective work it is necessary to use plates with a thickness of 6 mm and a width of 40 mm.

3. Application for bearing elements of the frame as a steel angle belt with a section of 50 × 5 mm is permissible only for seismic loads not higher than 8 points on the MSK-64 scale. For higher points, it is necessary to use more powerful sections according to the current assortment.

4. Analysis of the stress-strain state for steel frameworks of buildings and structures in India can be performed taking into account the requirements of the current standards of Ukraine and Russia, which allow for a more accurate assessment of local conditions and features of building structures.

References

[1] IS 1893-1, Criteria for earthquake resistant design, fifth rev., BIS, 2002.

[2] DBN B.1.1-12: 2006, Protection against dangerous geological processes, harmful use of fires, and fire. Construction in seismic areas of Ukraine, Minbud, Kiev, 2006.

[3] IS 808, Dimensions for the rolled steel beam, column, channel and angle sections, third rev., BIS, 2002.

[4] R. P. Johnson, Composite Structures of Steel and Concrete: Beams, Slabs, Columns and Frames for Buildings, Wiley Blackwell, 2018.

[5] DBN B.2.6-220: 2017, Coverage of buildings and structures, Min. region. Rozvitku, Kiev, 2017.

[6] SNiP II-7-81 *, Construction in seismic areas, Gossroj, Moscow, 2000.

[7] Zh. Bofang, The Finite Element Method. Fundamentals and Applications in Civil Engineering, Mechanical and Aeronautical Engineering, Wiley, 2018.

[8] S. R. Singiresu, The Finite Element Method in Engineering, sixth ed., Elsevier Inc., 2018.

[9] I. H. Shames, Energy and Finite Element Methods In Structural Mechanics, Routledge, New York, 2017.

[10] V. S. Karpilovsky, E. Z. Kriksunov, A. A. Maljarenko, S. Ju. Phialko, A. V. Perelmuter, M. A. Perelmuter, SCAD Office. Version 21. SCAD ++ software complex, SCAD Soft, Moscow, 2015.

[11] D. O. Bannikov, Estimation of practical convergence of the results of the analysis of plate models in the Finite Element Method, New Technologies in Building, 32, pp. 26-31. (2017).

[12] IS 875-2, for buildings and structures (other than earthquake) for buildings and structures, Part 2 - Imposed loads, second rev., BIS, 2010.