Calculation of the building of refrigeration equipment for progressive destruction

Elvira Egereva[1], *Dmitry* Gerasimov[1*]

[1]Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, 129337 Moscow, Russia

Abstract. The purpose of the calculation is to substantiate the fulfillment of the mechanical safety requirements for the design solutions of the building of refrigeration machines.The calculation confirms that in the process of operation, the building and its foundation will not reach the limit state in terms of strength, stability and deformations with the variants of simultaneous action of loads and impacts taken into account by this calculation.

1 Introduction

The forces arising in the building structures from the impact of the building on the foundation are calculated on the assumption of the elastic work of the foundation of the building.

The building of refrigeration machines is a frame three-story building with a technological basement [1-10]. The size of the building in the plan (in the axes) is 35,00x16,40 m, the total height above the mark is 0,000 – 13,5 m. The pitch of the columns in the longitudinal direction is 5.00 and 4,50 m, in the transverse direction – 6,80 and 4,80 m. The height of the floors: first - 3.8 m; the second – 3,65 m; third – 4,45 m; the refrigerating machine room is double-height, its height is 7,60 m; the height of the basement is 3.80 m. The height of the building to the top of the roof is 12,55 m. The elevated part of the building has marks 0,000, +4,050; +8,000; +12,965.

The calculation is made for the main and special combinations of loads and impacts. A special load is a seismic impact of the DE level with an intensity of VIII points according to the MSK-64 scales.

The calculation presents a check of the building for stability against progressive collapse.

2 Materials and methods

To assess the stability of the load-bearing structures of buildings against progressive collapse, two scenarios are considered as scenarios of local hypothetical destruction:
- the first scenario: to exclude from work the element of the column in the C/2 axis at el. minus 4,200 (in Figure 1).

* Corresponding author: varya.kirpichnikova@list.ru

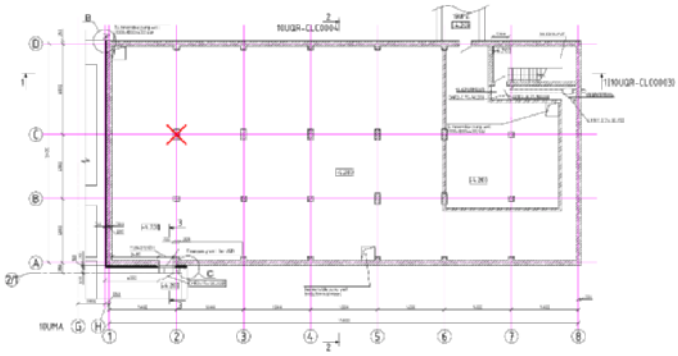

Fig. 1. Progressive Collapse Calculation Scenario with display of the excluded column.

Under the scenario of destruction of progressive collapse when the column is turned off from operation, the value of the coefficient K does not exceed 0,953 (no more than 95,3% of the strength is exhausted). The distribution of the coefficients for the use of the bearing capacity of reinforced concrete structures is shown in Figure 2.

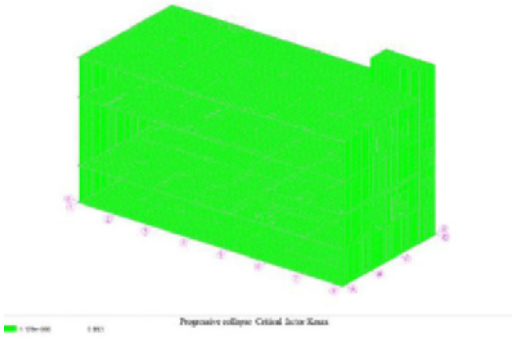

Fig. 2. Distribution of load- bearing factor of reinforced concrete structures.

The loads corresponding to the reactions in the removed column, taking into account the given dynamics coefficient to take into account the suddenness of the removal, are presented in Figure 3.

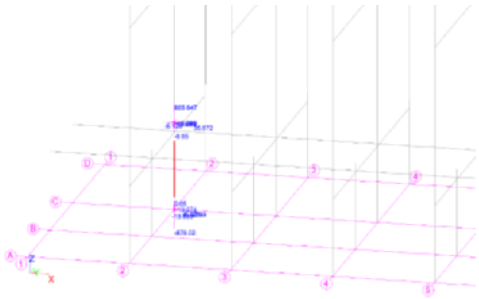

Fig. 3. Loads corresponding to reactions in the removed column, taking into account a given coefficient of dynamism to account for the suddenness of removal.

Figure 3 shows the following loads:
- longitudinal force N=878,02 kN;
- moment Mx=35,875 kN*m;

- moment My=13,074 kN*m;
- moment Mz=0,05 kN*m;
- transverse force Qx=6,126 kN;
- transverse force Qy=13,689 kN.

Forces N, M, Q in columns and floor beams when checking resistance to progressive collapse according to scenario No. 1 after removing the column are shown in Figures 4 - 8.

Forces in the floor slab at elev. minus 0.100 when checking resistance to progressive collapse according to the scenario after the removal of the column are presented in Figures 9 - 16. The direction of force output Nx1 in the elements of the floor slab coincides with the direction of the global X axis (along the alphabetic coordination axes) [11-16].

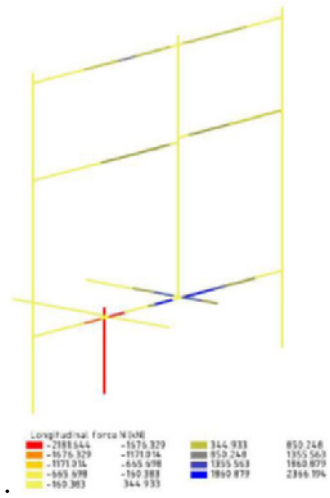

Fig. 4. Longitudinal force N in columns and floor beams when checking resistance to progressive collapse in accordance with the scenario, kN.

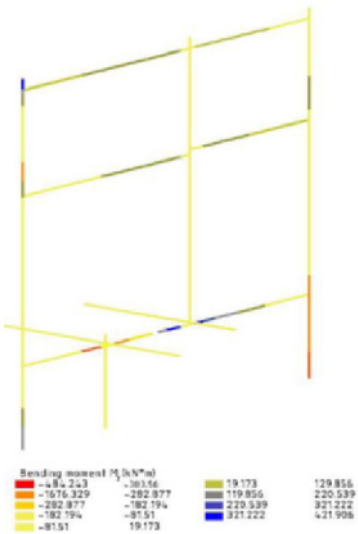

Fig. 5. The bending moment of My in the columns and beams of the ceiling when checking the resistance to progressive collapse in accordance with the scenario, kN*m.

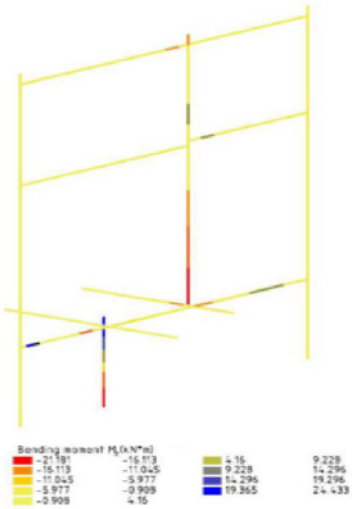

Fig. 6. Bending moment Mz in columns and floor beams when checking the resistance to progressive collapse in accordance with the scenario, kN*m.

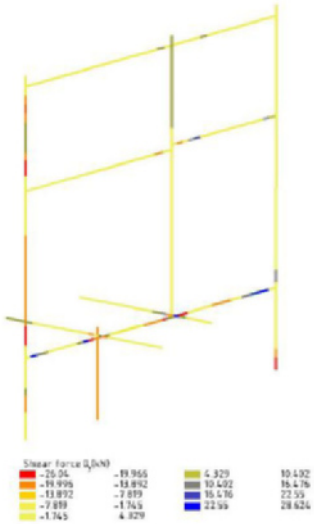

Fig. 7. Bending moment Qy in columns and floor beams when checking resistance to progressive collapse in accordance with the scenario, kN.

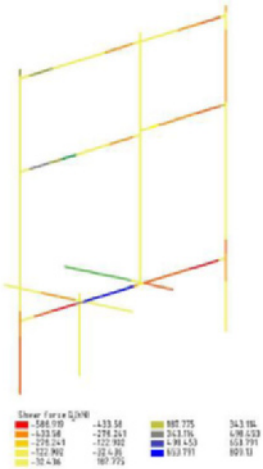

Fig. 8. Transverse force Qz in columns and floor beams when checking resistance to progressive collapse in accordance with the scenario, kN .

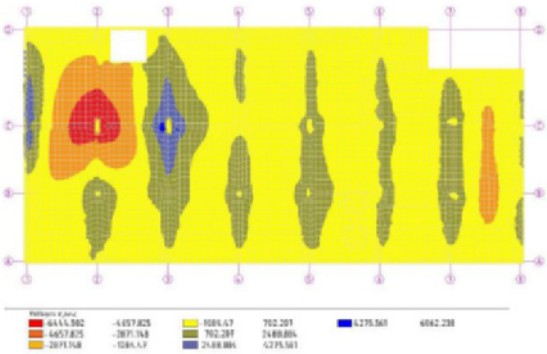

Fig. 9. Stresses σx in the lower surface of the floor slab at minus 0.100 when checking the resistance to progressive collapse in accordance with the scenario, kPa.

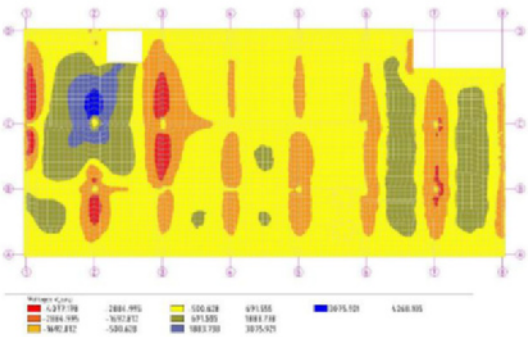

Fig. 10. Stresses σx on the upper surface of the plate at minus 0,100 when checking the resistance to progressive collapse in accordance with the scenario, kPa.

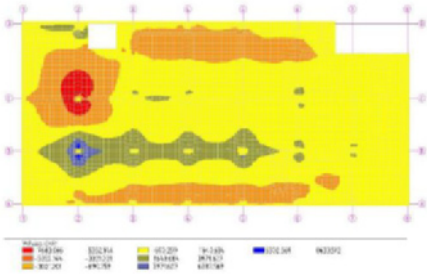

Fig. 11. Stresses σy in the lower surface of the floor slab at minus 0.100 when checking the resistance to progressive collapse in accordance with the scenario, kPa .

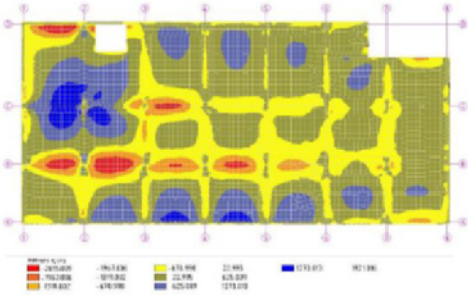

Fig. 12. Stresses σy in the upper surface of the floor slab at minus 0.100 when checking the resistance to progressive collapse in accordance with the scenario, kPa.

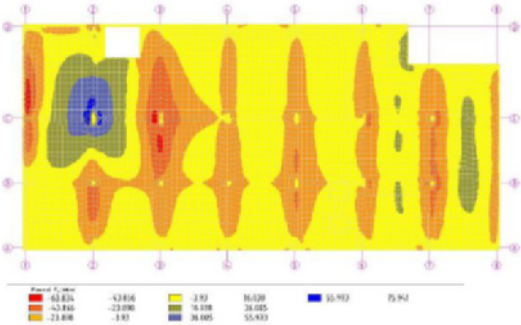

Fig. 13. The moment Mx in the overlap plate at minus 0,100 when checking the resistance to progressive collapse in accordance with the scenario, kN*m.

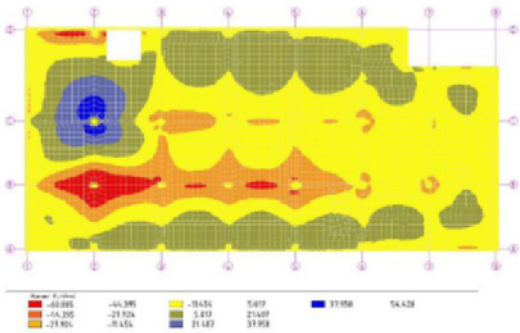

Fig. 14. The moment of My in the floor slab at minus 0.100 when checking the resistance to progressive collapse in accordance with the scenario, kN*m.

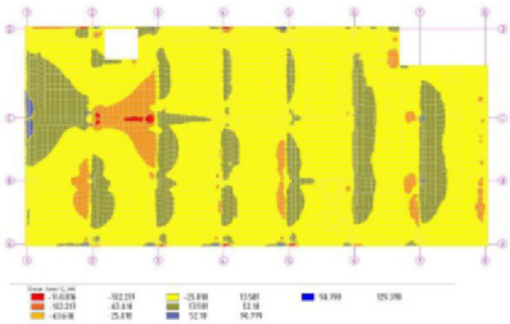

Fig. 15. The transverse force Qx in the floor slab at minus 0.100 when checking the resistance to progressive collapse in accordance with the scenario, kN.

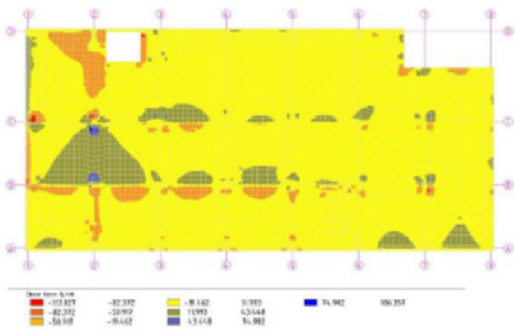

Fig. 16. The transverse force Qy in the floor slab at minus 0.100 when checking the resistance to progressive collapse in accordance with the scenario, kN.

Vertical displacements of columns, beams and floor slabs when checking resistance to progressive collapse according to scenario No. 1 are shown in

Figure 17.

Vertical displacements of columns and floor beams when checking resistance to progressive collapse according to scenario No. 1 are shown in Figure 18.

The maximum allowable deflection is taken equal to 1/50 of the span [18].

Vertical displacements of floor slabs and beams caused by local destruction according with the scenario are determined taking into account SP 52-103-2007 [19]. The initial modulus of elasticity of concrete is assigned taking into account reduction factors [20-22].

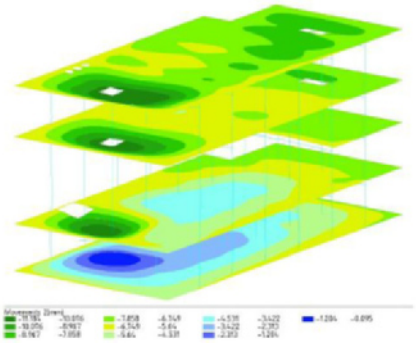

Fig. 17. Vertical movement of columns, beams and slabs of building slabs when checking the resistance to progressive collapse according to the scenario, mm

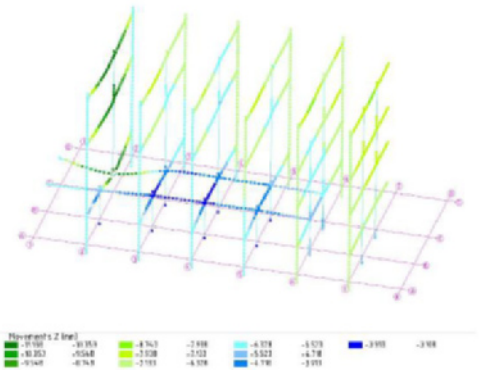

Fig. 18. Vertical movements of columns and beams of floor slabs when checking resistance to progressive collapse according to the scenario, mm.

The span between the columns in the B/2-D/2 axes is l0 = 11,6 m. The vertical maximum deflection at the span l = 11.6 m is fпр =l/50=11.6/50=0,232 m = 232,0 mm. The maximum deflection of the floor slab at elev. minus 0,100, caused by local destruction according to the scenario, taking into account the reducing coefficient of the concrete deformation modulus, is f = 11,2 mm, which is less than the ultimate deflection equal to fпр = 232,0 mm.

3 Conclusion

The obtained results of calculating the building frame for progressive collapse substantiate the fulfillment of the mechanical safety requirements for the load-bearing elements of frame buildings, and also show that when one column of the lower floor excluded from the frame, the internal forces will be redistributed, as well as significant displacements of the floor elements, but the building, in as a whole, will not collapse. The calculation confirms that during operation the building of refrigeration machines and its base will not reach the

limit state in terms of strength, stability and deformations under the variants of simultaneous action of loads and impacts taken into account by this calculation.

Based on this calculation, we see that under given loads on the building, the structure retains its properties and can operate in normal mode without a threat to human life and health and the environment.

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