Applied Mechanics and Materials Vols. 578-579 (2014) pp 615-618
© (2014) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.578-579.615

A Joint of Ceramic Granite Mount by Threaded Anchor Studs in a Suspended Ventilated Facade

Valentina Tusnina[a], Alexey Emelyanov[b] and Olga Tusnina[c]
Moscow State University of Civil Engineering (MGSU)
129337, Russia, Moscow, Yaroslavskoe shosse, 26
[a]valmalaz@mail.ru, [b]snegiri_emelianov@mail.ru, [c]lazoltus@mail.ru

Keywords: a suspended ventilated facade, ceramic granite cladding, threated anchor studs

Abstract. Suspended ventilated façades are the most common types of finishing and heat insulation of existing buildings and construction projects. There is a great variety of cladding materials employed for suspended ventilated façades, the most popular being ceramic granite. Ceramic granite cladding became widely used because it helps implement in-demand architectural solutions and simplify panel mounting. The article describes a new design solution for suspended ventilated façades, developed by the authors.

Introduction

Today, a large number of suspended ventilated façade systems exist, featuring different cladding materials, subframe designs and materials of bearing structure. These systems have, as their bearing part, a structure comprised of brackets with extensions, guide rails, and cladding subframe fasteners. Ceramic granite rainscreen cladding systems are of widespread use in Russia.

There has been developed a suspended ventilated facade system with 600x600mm ceramic granite cladding panels different in that, unlike existing solutions, it provides a nodal fixing of the cladding, and replaces vertical rails with a perforated tape and support (wind-load) brackets with threaded anchor studs. The perforated tape being put in tension transfers the load exerted by the cladding weight from anchor studs to carrier brackets attached to floor slabs. In earthquake-prone regions, an additional perforated tape is placed horizontally to ensure the rigidity of anchor studs.

Thermal analysis

The presence of heat-conductive fixing elements such as brackets and anchors is an important factor that influences thermal properties of existing systems. The said elements decrease thermal uniformity factor of the rainscreen structure, which influences building's thermal effectiveness as a whole [1]. The system developed features higher reduced R-value due to lower heat losses versus those observed in existing systems. This is confirmed by a thermal calculation performed using a TEPL computing program that provides a numerical solution of the problem of 3D stationary thermal conductivity where two facade systems (the new and conventional ones) were analysed [2].

The analysis of results of the thermal calculation showed that when compared with today's commonly used facade system, the new system design has better thermal properties due to high reduced R-value and high thermal uniformity factor. The new system has a reduced R-value of 1.352 $m^2 \cdot {}^oC/W$, which is 11.3% higher than that of existing systems equal to 1.199 $m^2 \cdot {}^oC/W$. The thermal uniformity factor of the new system (0.753) is higher than that of existing similar system (0.668), which proves better energy performance of the former. The calculation was made for a galvanised steel rainscreen system.

Higher values of the thermal uniformity factor result from the fact that a bracket of the conventional system is significantly more heat-conductive than a threaded anchor stud of the new system, which is seen in the heat patterns in Fig. 1.The cross-sectional area of the U-bracket of the conventional system is larger than that of the anchor stud, with the support pad of this bracket being a major contributor to the lowering of thermal uniformity factor of the structure.

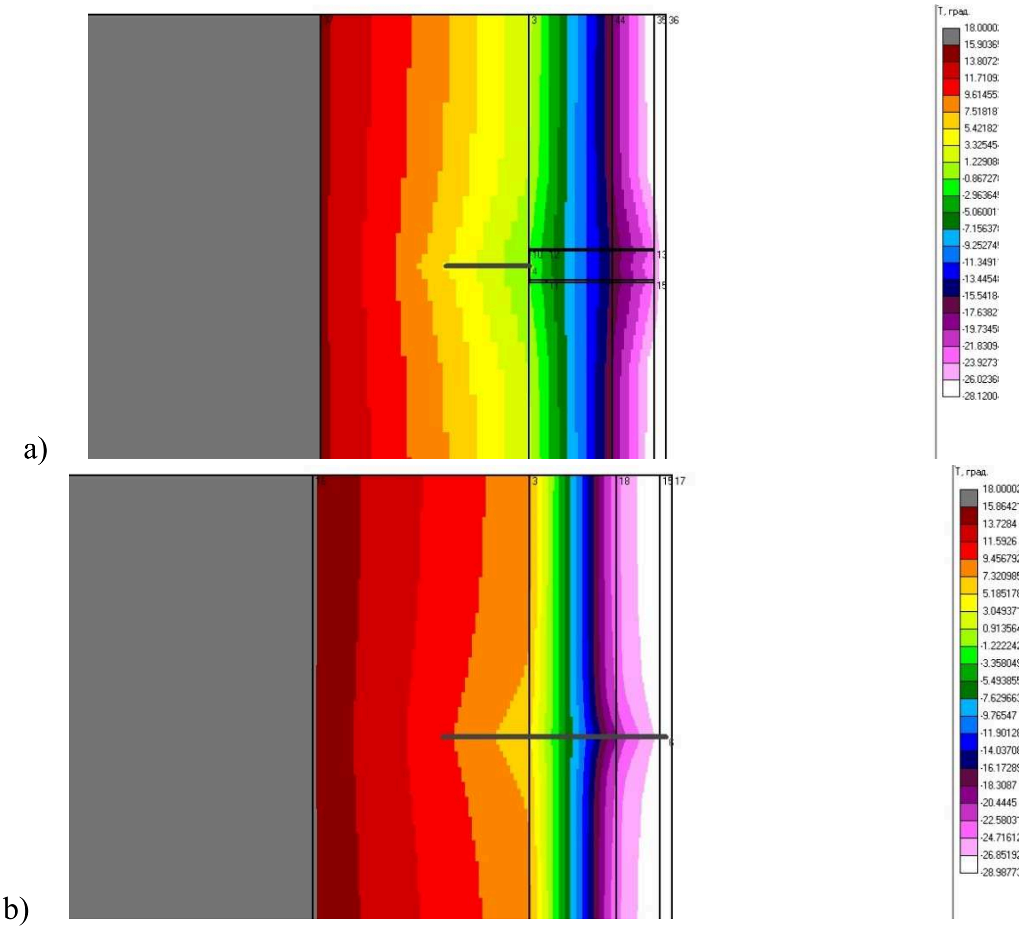

Figure 1. Temperature isothermal fields in plan view
a) for the conventional system bracket; b) for the threaded anchor stud of the new system

A numerical static analysis

A static analysis of the system was made by using of a LIRA software. The finite-element model of the system is depicted in Fig. 2.

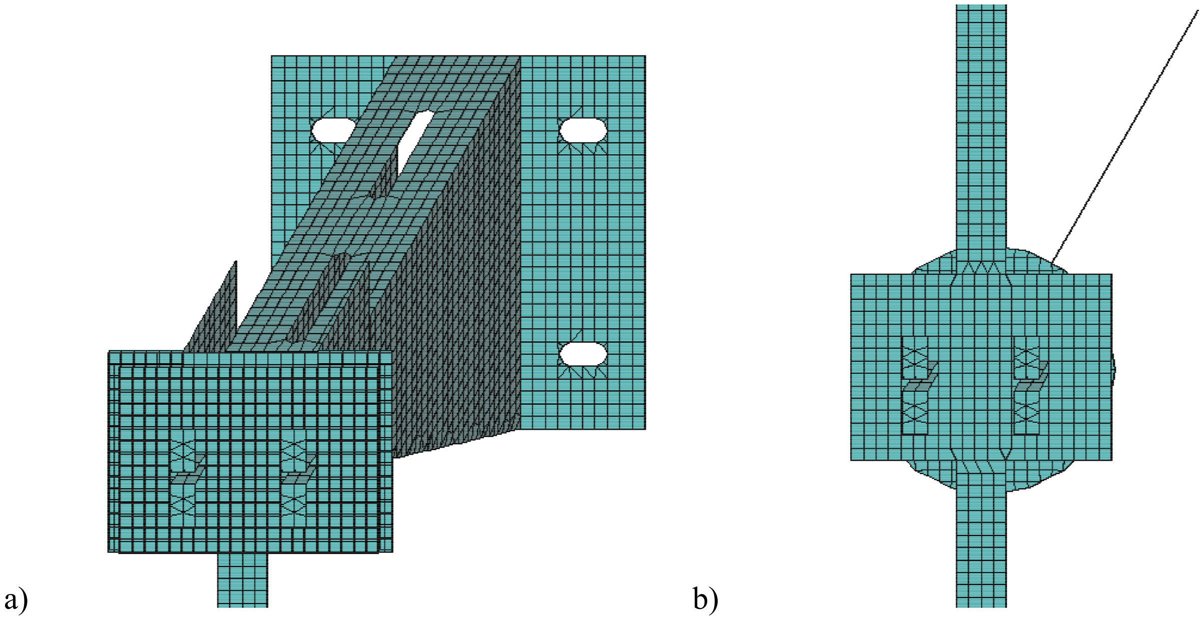

Figure 2. System's finite-element model
a) mounted with carrier bracket; b) mounted with threaded anchor stud

Brackets are put in tension and compression. The highest stresses occur in tension as wind-suction forces acting in the air gap are considerably stronger than those exerted by wind on the outer façade. Consequently, the maximum stresses (tension stresses) were considered in the strength analysis (for the first limit state). Table 1 provides stress values for brackets in the row and corner areas of the rainscreen.

Table 1.
Stress Values in Corner Area Versus Building Height (Z) and Wind Region

	Stress Values Ϭ=Ny/A+M/Wx, MPa in Corner Area (Carrier Bracket)						
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**
Z=5m	13	13.5	14.2	14.9	15.9	16.9	17.9
Z=10m	13.4	14.1	14.8	15.8	17	18.3	19.4
Z=15m	13.7	14.4	15.3	16.4	17.7	19.2	20.5
Z=20m	13.9	14.7	15.7	16.9	18.3	19.9	21.4
Z=25m	14.1	15	16	17.3	18.9	20.5	22.1
Z=30m	14.3	15.2	16.3	17.7	19.3	21.1	22.7
Z=35m	14.4	15.4	16.6	18	19.7	21.6	23.3
Z=40m	14.6	15.6	16.8	18.3	20.1	22	23.8
Z=45m	14.7	15.8	17	18.5	20.4	22.4	24.3
Z=50m	14.8	15.9	17.2	18.8	20.7	22.8	24.7
Z=55m	14.9	16.1	17.4	19	21	23.1	25.1
Z=60m	15	16.2	17.6	19.2	21.3	23.5	25.5
Z=65m	15.1	16.3	17.7	19.5	21.5	23.8	25.9
Z=70m	15.2	16.4	17.9	19.6	21.8	24.1	26.2
Z=75m	15.3	16.6	18	19.8	22	24.4	26.6
	Stress Values Ϭ=Ny/A+M/Wx, MPa in Corner Area (Wind-Load Bracket)						
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**
Z=5m	5	6.6	8.3	10.5	13.1	16	18.6
Z=10m	6.2	8.1	10.2	12.9	16.1	19.6	22.9
Z=15m	7	9.1	11.5	14.5	18.2	22.1	25.8
Z=20m	7.6	9.9	12.6	15.9	19.9	24.2	28.1
Z=25m	8.2	10.7	13.5	17	21.3	25.9	30.2
Z=30m	8.6	11.3	14.3	18	22.5	27.4	31.9
Z=35m	9	11.8	14.9	18.9	23.6	28.7	33.4
Z=40m	9.4	12.3	15.6	19.6	24.6	29.9	34.8
Z=45m	9.8	12.8	16.2	20.4	25.5	31.1	36.2
Z=50m	10.1	13.2	16.7	21.1	26.4	32.1	37.3
Z=55m	10.4	13.5	17.2	21.7	27.1	33	38.4
Z=60m	10.7	14	17.7	22.3	27.9	34	39.6
Z=65m	11	14.3	18.1	22.9	28.7	34.9	40.6
Z=70m	11.2	14.6	18.5	23.4	29.3	35.6	41.4
Z=75m	11.5	15	19	24	30	36.5	42.5

The analysis of results of the numerical studies confirms the possibility of using the system in buildings as high as 75 m in all wind regions and with all possible standoff distances of ceramic granite cladding (200 mm max).

Experimental study

Dynamic load tests were carried out on the new system. A pendulum vibration rig designed by Central Scientific Research Institute for Building Structures named after V.A. Kucherenko was used to test the system. The tests aimed to assess whether the system is suitable and reliable enough to be used in buildings erected in earthquake-prone regions measured 7 to 9 points on MSK-64 macroseismic scale [3]. The below photo (Fig. 5) depicts the system attached to the test rig.

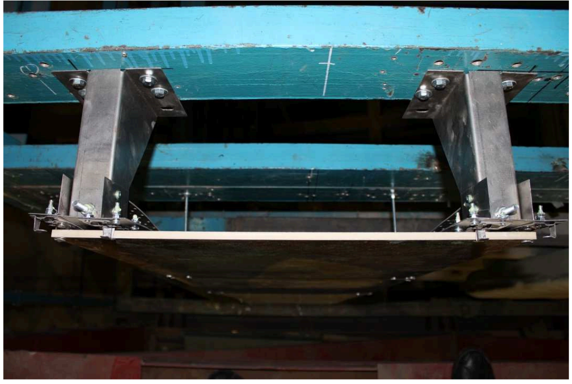

Figure 3. System Attached to Test Rig (Top View)

The rig simulated seismic loads measuring 7–9 points. Vibration acceleration varied from 1.13 to 7.77 m/s^2. Vibration frequencies ranged from 2.1 to 7.2 Hz, and vibration amplitudes - 0.9 to 21.5 mm. Different points of the façade had the acceleration ranged within 0.01 to 24.84 m/s^2. The structure resonated when the natural frequencies of vibrations of the system equalled the frequencies of forced vibrations of the rig. Resonance was observed at different load steps at a frequency of 4.4 Hz; no failure of the structure occurred. This leads to the conclusion that the new system can be used in earthquake-prone regions rated 9 points on the 12-point MSK-64 scale.

Cost analysis

The practicality of the system was economically assessed. A manufactured pilot batch of system elements showed that 1 sq. m of the bearing structure will cost RUB 612. This cost embodies costs for manufacturing subsystem elements and costs of expendables and fits in the current price range for existing systems (460–1 000 RUB). Note that prices announced to us by manufacturers while calculating the cost of a system are not representative and might have been deliberately overstated. Therefore, the cost of the system can be reduced through the upgrade of technology and equipment involved in the production of system elements. We calculated the cost for the maximum cladding standoff distance (250 mm). Consequently, the cost will be less if the distance is shortened.

Summary

Experimental and theoretical studies revealed that the developed subframe design features better thermal properties and proves to be reliable for use in all wind and earthquake-prone regions, in buildings of varied height (up to 75 m) with a 200mm standoff distance. The application of the system in said buildings is economically sound and practical.

References

[1] Gagarin V. G., Dmitriev K.A. 2013 *Thermal Non-Uniformities to be Factored into Analysis of Heat Shielding of Walling in Russia and European Countries*, Building Material,No.6,14-17pp.

[2] Tusnina O.A., Emelyanov A.A., Tusnina V.M. 2013 *Thermal Properties of Various Subframe Systems of Rear-Ventilated Rainscreen Façades.* Magazine of Civil Engineering, No. 8 (43), 54–63 pp.

[3] MSK-64. MSK Seismic Intensity Scale. 1964.