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Research on Calculation Method of Basket of High-rise Building Rescue System

Duong Truong Giang[1]
[1]*Faculty of Mechanical Engineering, Hanoi University of Civil Engineering, Hanoi, Vietnam.*

Abstract:
According to the development trend, many high-rise buildings will be built. Along with it is the need for an escape solution when there is a problem for people living and working in it. Therefore, the new rescue system is a combination of lifting baskets and ladders installed outside the building, helping to rescue adults, children and the elderly at the same time. The structure of the lifting basket is set out to ensure that when storing and transporting, the basket is removed and stowed. When installing for rescue use, the lift basket are assembled quickly.The basket structure ensures safety, the stress does not exceed the allowable value and can meet the requirements of the load and relevant standards. However, the method of calculating the basket for the rescue system has not been published many studies.Therefore, this paper will study the calculation method, applied to evaluate the basket of the rescue system that we have just proposed.

Key Word*:basket and ladders, effective load, rescue system, strength assessment.*

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I.Introduction

According to the development trend, many high-rise buildings will be built. Along with it is the need for an escape solution when there is a problem for people living and working in it. The rescue system from the outside of the building has had many published patents and related studies. Each rescue system in these studies has its own advantages and disadvantages.The invention of the high -rise rescue system and the rail is the cable for the moving basket, this system slides on the cable and the basket has no door there[1]. This rescue system is relatively complicated and for professional forces. Another invention is the high -rise rescue system with fixed rails into the building so that the basket will move, use gear - dental rods[2,3]. These are fixed and difficult systems to rescue the number of adults. A rescue system with baskets will allow easy rescue of both the elderly and children. In other studies, there has been patent for personal rescue bags in an emergency[4]. However, this application is only for healthy people.

A new rescue device system is a combination of lifting basket and ladder installed outside the building at locations such as windows and balconies with many advantages (Figure 1). The basket is operated simultaneously when someone climbs on the ladder, adults, children and the elderly can be rescued at the same time[5]. To design a rescue system installed on the outside of the building, we have studied the design and optimization of the winch for mounting on the basket[6,7]. The winch in the study can be used as a personal rescue device for a normal healthy person and it also incorporates pulling the lifting basket that slides on the guide ladder.

Data on materials, ladders, and standard lifting equipment has been stated in many different documents such as FEM 1001, ANSI A 14.2, BS5655[8,9,10,11]. The CREO and ANSYS softwares have been used to model and stress analysis of ladder structure that is built up with CRP and GRP composite circular rods. With the help of ANSYS studies, a comparative study on stresses developed in both CRP and GRP ladder structure is made[12].However, the method of calculating the basket for the rescue system has not been published many studies.

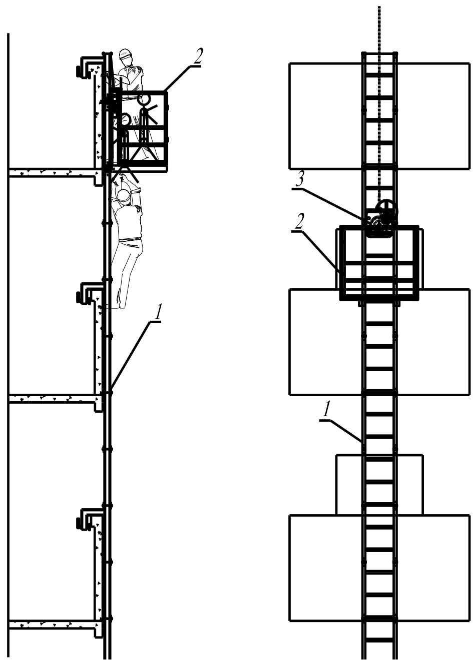
In this study, we will present a basket structure plan to meet the requirements of this new rescue system[5]. Research methods to calculate and evaluate the durability of baskets to meet safety requirements according to relevant standards.

II. Geometry of The Basket

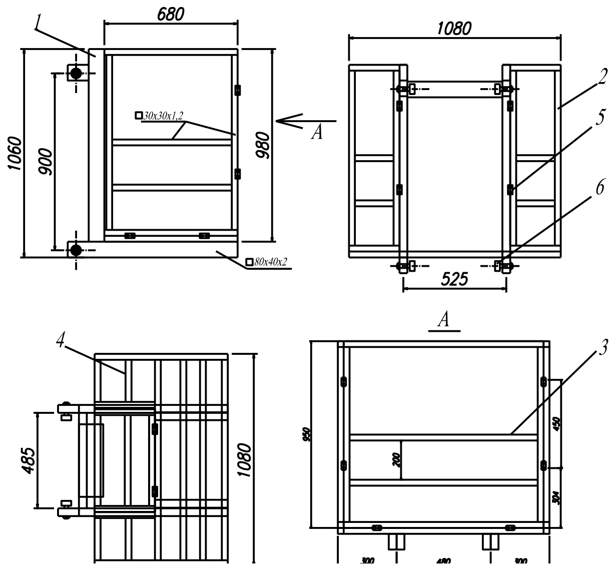
For lifting baskets common in practice are square and rectangular baskets, the statistics are shown in Table1.Depending on the size of the ladder, the arrangement of the winch, the basket design is 0.68x0.98x1.08,basket capacity is 136kg. The basket of the rescue system in this study consists of a lifting basket frame, side, bottom, back, and sides joined together by quick-release hinge joints (Figure 2). Basket made of 6061 aluminum alloy material, must be used and installed conveniently. During storage and transportation, the basket is removed and stowed. When installing for rescue use, the assemblies are assembled quickly by latches - hinge joints, the winch is fixed to the bearing frame, theguide wheels of the lifting basket will run along the guide rails on the ladder. The bottom of the basket has a bottom one-way flip-down door for moving from below the ladder to the lifting basket.

Table1:Basic dimensions of lifting baskets [5,13]

Basket shape	Dimensions, mm	Load carrying capacity, kg
Rectangular basket	0.71x0.96x1.06	136
	0.91x1.52x1.06	271
	0.91x2.13x1.06	408
Square basket	0.71x0.71x1.06	136
	0.96x0.961x1.06	271
	1.22x1.22x1.06	408



1. Ladder, 2. Basket, 3. Winch.
Figure1.1: Rescue system for the outside of the building



1. Basket frame, 2. Side view, 3. Bottom face, 4. Back side, 5. Quick release hinge joint, 6. Guide wheel.
Figure.2.1: Basket structure

III. Method of Calculating TheBasket of The Rescue System on High-rise Buildings

Loads acting on the basket by people and tools calculated by the model in Figure 3:

$$F = \psi S_L; \quad \psi = 1 + \frac{a}{g} \qquad (3.1)$$

Where, the dynamicload factor ψ is calculated with the maximum design acceleration when motion stops suddenly [5], $a = 6,1$ m/s^2 ; gravity acceleration $a = 9,8$ m/s^2; S_L is the weight of the person on basket and tools.

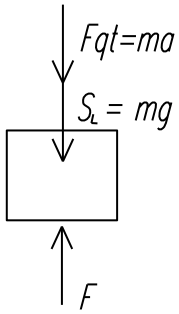


Figure.3.1: Model for calculating the load to the basket

The position of the assumed deflection load placed on the bottom of the basket is calculated characterized by the deviation e_x and e_y. Deviation e_x and e_y, we can determine two positions to place the load on the bottom of the basket. According to standard BS 5655 determine the position of eccentricity with normal people and goods.

$$e_x = \frac{D}{4}; e_y = \frac{B}{4} \qquad (3.2)$$

Where, B is the basket width,mm; D is the basket depth, mm.

The weight of the basket itself S_G including the weight of the winch and other components is G_t, the weight of the basket structure G. Load factor $\gamma_c = 1$, calculated load case consider:

$$\gamma_c(S_G + \psi S_L) \qquad (3.3)$$

Using the finite element method to analyze the structure by SAP2000 software to calculate and simulate the basket frame at two load combinations COM1 and COM 2. Load combination COM1 includes self-load with acceleration when lowering and concentrated load deflected at position 1. Load combination COM2 includes self-load with acceleration when lowering and concentrated load deflected at position 2. Displacement of basket structure calculated by SAP2000 software and checked by standard AA-ASD 2000 in the program.The internal force in the structure calculated by the finite element method by SAP2000 software is the basis of stress calculation according to the standard FEM1.001.

The stress σ in the basket structure is tested by formula (4) with the assumption that the element is subjected to longitudinal bending[10]:

$$\sigma = \frac{P}{\varphi A} + \frac{M_2}{W_2} + \frac{M_3}{W_3} < [\sigma]; \ [\sigma] = \frac{\sigma_{ch}}{n} \qquad (3.4)$$

Where, P is the axial force of the element ; φ is the longitudinal bending coefficient in the case of the element in compression; A is the element cross-sectional area; M_2 and M_3 is the bending moment at the cross-section; W_2 and W_3 is the bending moment withneutral axes; σ_{ch} is the yieldstrength ; n is the factor of safety.

Equivalent stresses in combined compression, bending and shearing:

$$\sigma_{cp} = \sqrt{\sigma^2 + 3\tau^2} < [\sigma] \qquad (3.5)$$

From the data given in Table 2, dynamic load factor $\psi = 1.622$, effective load $F = 2272$ N, position of loading on the bottom of the basket $e_x = 170$ mm, $e_y = 270$ mm define two load locations,calculation diagram and load case as shown in Figure 3.2.

Table 2: The given parameters

Parameter	Value
Basket width	B =1080 mm
Basket depth	D =680 mm
Total weight of people on basket and tools	S_L =1400.7 N
Weight of winch set on basket	G_t =126.6 N
The yield strength of aluminum 6061	σ_{ch} =280 N/mm^2
Poison's coefficient	μ=0.34
The density of aluminum	ρ=2.73g/cm^3
The factor of safety	n= 1.5
Cross-section of the bearing frame of the basket structure,(Type section 1)	Box 80x40x1.5
Another cross-section of the basket structure, (Type section 2)	Box 30x30x1

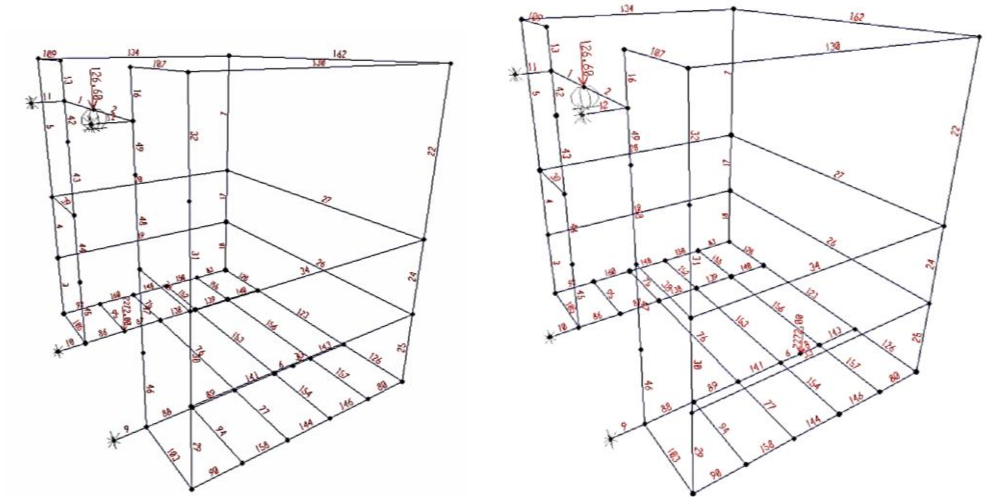


Figure 3.2: Calculation diagram in two load combinations COM1 and COM2

IV. Result

Calculation results from SAP2000 software, we have reaction force on ladder, displacement value, internal force. The internal force in the structure calculated by the finite element method by SAP2000 software is the basis of stress calculation according to the standard FEM1.001.

Table 3: Reaction force on ladder

COM1	COM2
Ry = -152,53 N; Rx = -420 N, Rz = 0 Ry = -316,95 N; Rx = -242,66 N, Rz = 0	Ry = -594N; Rx = -30,34N, Rz = 0 Ry = -914N; Rx = 693N, Rz = 0
Ry = 151,53 N; Rx = 405,59N, Rz = 0 Ry = 257,08 N; Rx = 316,85N, Rz = 0	Ry = 594N; Rx = -181N,Rz = 0 Ry = 914N; Rx = - 481N,Rz = 0

In which, the maximum vertical displacement at the load combination COM2 is 10.18489mm. Maximum equivalent stress at load combination COM2, for type 1 box section 80x40x1.5: $\sigma_{cp} = 75N / mm^2 < [\sigma] = 210.5N / mm^2$,for type 2 box section 30x30x1: $\sigma_{cp} = 80.6N / mm^2 < [\sigma] = 210.5mm^2$. The calculated results according to the proposed method show that the basket structure is safe enough and can be applied to the product.

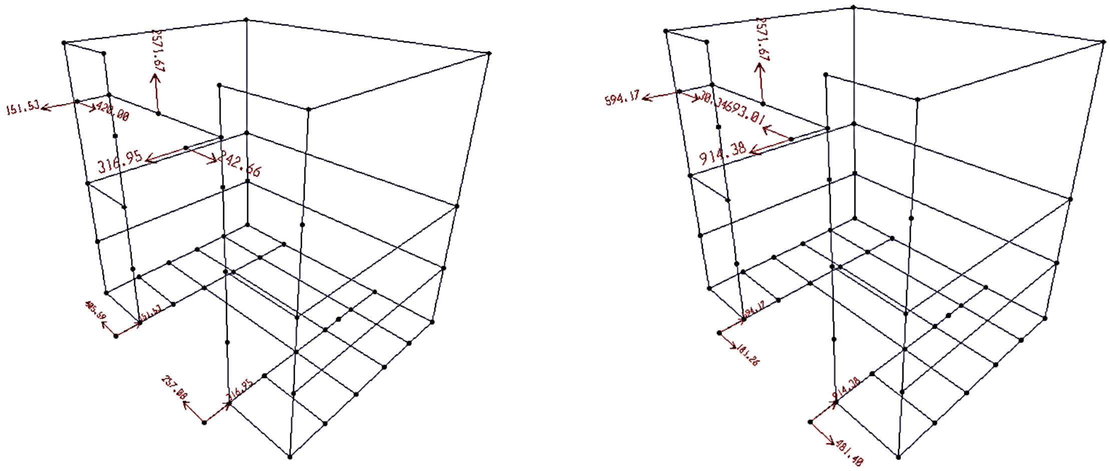


Figure 4.1: The largest reaction on the ladder and cable tension

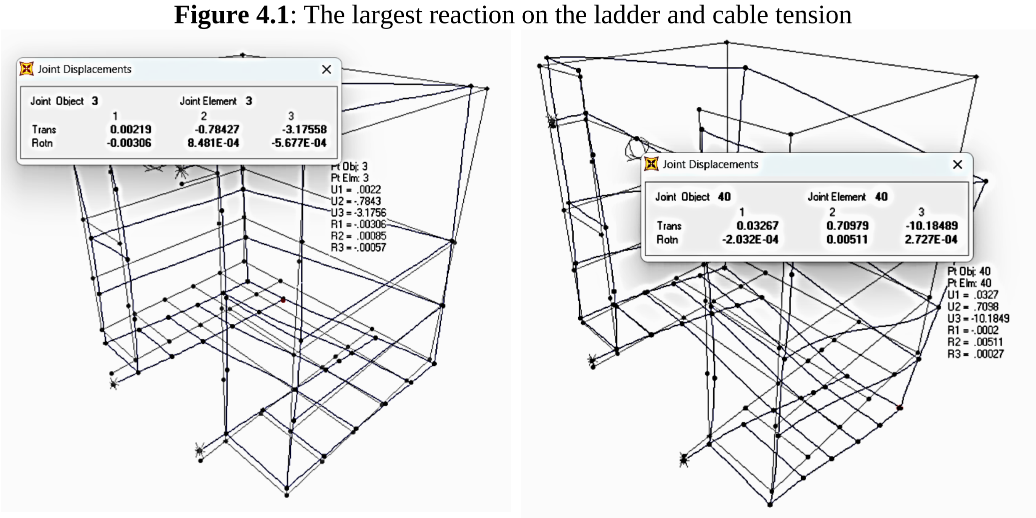


Figure 4.2: Maximum displacement

Table 4: Summary of the results of calculating the section type 1

Element	Load combination	Vertical force P ,kN	Bending moment M_2 ,kNmm	Bending moment M_3 , kNmm	Calculation length L_{tt} ,mm	Slenderness factor λ	Coefficient safe, n	Longitudinal bending coefficient, φ
42	COMB1	2.3	-210.5	12.7	132.0	7.9	1.5	1.0
45	COMB2	0.7	-52.3	-285.8	256.0	15.2	1.5	1.0
46	COMB2	1.4	85.9	-495.7	256.0	15.2	1.5	1.0
88	COMB2	-0.2	26.5	-498.3	160.0	9.5	1.5	1.0
Element	Load combination	Radius of gyration, r_{min} , mm	Area of cross-section, A , mm^2	Setion modulus W_2 , mm^3	Setion modulus W_3 , mm^3	Allowed stress $[\sigma]$, N/mm^2	Stress σ , N/mm^2	Assess
42	COMB1	16.8	351.0	5,082.2	7,475.6	210.5	49.6	Satisfied
45	COMB2	16.8	351.0	5,082.2	7,475.6	210.5	50.4	Satisfied
46	COMB2	16.8	351.0	5,082.2	7,475.6	210.5	87.3	Satisfied
88	COMB2	16.8	351.0	5,082.2	7,475.6	210.5	72.4	Satisfied
Element	Load combination	Local coordinates	Shear force V_2 , kN	Shear force V_3 ,kN	Torque T ,kNmm	Static moment S , mm^3	Moment of inertia I , mm^4	Torque resistance W_{x0} , mm^3
42	COMB1	0.00	0.19	-0.47	8.46	4,578	299,023	4,533
45	COMB2	256.00	0.34	0.12	-13.62	4,578	299,023	4,533
46	COMB2	0.00	-0.60	0.28	-5.21	4,578	299,023	4,533
88	COMB2	0.00	-1.17	0.06	49.63	4,578	299,023	4,533
Element	Load combination	Local coordinates	Shear stress τ , N/mm^2	Stress, σ , N/mm^2	Equivalent	Allowed stress $[\sigma]$,	Assess	Type section

					stress σ_{cp}, N/mm^2	N/mm^2		
42	COMB1	0.00	1.9	49.6	49.7	183	Satisfied	1
45	COMB2	256.00	3.1	50.4	50.7	183	Satisfied	1
46	COMB2	0.00	1.3	87.3	87.3	183	Satisfied	1
88	COMB2	0.00	11.1	72.4	75.0	183	Satisfied	1

Table 5: Summary of the results of calculating the section type 2

Element	Load combination	Vertical force P ,kN	Bending moment M_2 ,kNmm	Bending moment M_3, kNmm	Calculation length L_{tt} ,mm	Slenderness factor λ	Coefficient safe, n	Longitudinal bending coefficient, φ
18	COMB2	0.06	-36.51	-27.44	824.00	69.59	1.5	1
34	COMB2	0.02	11.88	-64.85	824.00	69.59	1.5	1
126	COMB2	0.16	4.99	71.00	262.00	22.13	1.5	1
130	COMB2	0.16	30.74	-55.10	824.00	69.59	1.5	1
Element	Load combination	Radius of gyration, $r_{\min}$,mm	Area of cross-section, A, mm^2	Setion modulus W_2, mm^3	Setion modulus W_3, mm^3	Allowed stress $[\sigma]$, N/mm^2	Stress σ, N/mm^2	Assess
18	COMB2	116	1,085.24	1,085.24	116	210.5	59.4	Satisfied
34	COMB2	116	1,085.24	1,085.24	116	210.5	70.9	Satisfied
126	COMB2	116	1,085.24	1,085.24	116	210.5	71.4	Satisfied
130	COMB2	116	1,085.24	1,085.24	116	210.5	80.5	Satisfied
Element	Load combination	Local coordinates	Shear force V_2, kN	Shear force V_3 ,kN	Torque T ,kNmm	Static moment S, mm^3	Moment of inertia I, mm^4	Torque resistance W_{x0}, mm^3
29	COMB2	0	-0.24	0.13	-1.10	631	16,278.6	841
34	COMB2	0	-0.16	0.02	1.41	631	16,278.6	841
126	COMB2	0	0.41	0.03	12.52	631	16,278.6	841
130	COMB2	0	-0.13	0.06	1.85	631	16,278.6	841
Element	Load combination	Local coordinates	Shear stress τ, N/mm^2	Stress, σ N/mm^2	Equivalent stress σ_{cp}, N/mm^2	Allowed stress $[\sigma]$, N/mm^2	Assess	Type section
29	COMB2	0	1.4	69.1	69.2	183	Satisfied	2
34	COMB2	0	1.7	70.9	70.9	183	Satisfied	2
126	COMB2	0	15.0	71.4	76.0	183	Satisfied	2
130	COMB2	0	2.3	80.5	80.6	183	Satisfied	2

IV. Conclusion

In this paper, the new rescue system for the outside of the building and the basket structure was introduced. The basket is operated simultaneously when someone climbs on the ladder. Adults, children and the elderly can be rescued at the same time. The basket structure plan ensures that when storing and transporting, the basket is removed and stowed. When installed for rescue use, the basket assemblies are assembled quickly. The results obtained are as follows:

- Research the method of calculating the basket in accordance with the structural characteristics and related regulations

- Numerical testing of a basket model with the help of SAP2000 software and stress assessment in accordance with relevant standards.

The engineering model can pass all durability ratings to meet safety requirements, can be used in real products. In the next study, it will be to optimize the structure and materials of the basket, to study the effect of emergency braking when moving.

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