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Steel-Concrete Structures in 24 Storey Bank Building in Bratislava

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Summary

Last trends in construction technology of multistorey buildings. Steel skeleton stiffened by means of concrete elements. Fire protection of steel parts solved by embedding concrete. By a combination of various material-structural elements and technology an optimum could be achieved. At VÚB-Center Building constructed in combined technology with dominance of concrete have been solved by means of steel in the most exposed parts: the inner piers in ground floor cantilevered transverse plate with embedded steel grid, the statically most exposed facade columns.

1.Structural and construction technology of multistorey buildings-last trends

The multistorey buildings for civil and industry purposes could be realized in various structural, material and construction technology. It is to accent the great liaison of all these components. A competion exists among the construction systems, concerning the choise many and various criteria are important, often of conjuctural character and different in the countries. In steel skeleton some development trends could be distinguished:

1. Pure steel skeleton is rarely used, the spatial stability is mostly achieved by means of concrete elements, e.g. by concrete floor stabs, shear walls and cores.
2. The minimalisation of structural parts designed in steel - e.g. steel-sheet and r. concrete floor slab substituted by r. concrete stab, beam elements and/or columns by composite ones
3. The minimalisation of steel parts which have to be protected against corrosion and fire. The most simple and cheap solution is their embedding with concrete.
4. To enable the joining at concrete structures the use at progressive components - in formwork, reinforcing, geometry accuracy, precasting etc.
5. As last trend to win an optimal solution is a mixed structural system using various material-structural parts and/or elements and by following in-situ concrete to achieve a stiff monolitic structure. The following described building is realized in that technology.

2. VÚB - Bank Center building in Bratislava

2.1 Generally about the building

In Bratislava a 24 storey bank building has just been finished, where a combination of steel-concrete structures has been used (Fig. 1). The layout has the ellipse form with main dimensions of 25,2 x 48,0 m with the communication and instalation core 10 x 18 m in the excentrical position (Fig. 2). In the cross direction are the rigid frames in 6 m distance with middle span of 9,6 m, enough flexible in horizontal direction, so that their participation on carrying horizontal loading is negligible, all effects of horizontal loading is carryied by the core with joined shear walls supplemented by torsion forces. The top part of the ellipse is in the ground floor cantilevered 6 m.

For bearing structures a mixture of various material technology has been used:
- in-situ concrete: the core, shear walls and the inner columns
- in precast concrete: the peripheral elliptical parapeth girders, most facade columns
- in composite concrete: the floor structures with prefabricated lower part and in-situ concrete upper layer (slab and cross beams)
- composite steel - reinforced concrete: the inner columns in 1st and 2nd floor, the transverse plate over 2nd floor carrying cantilevered part of the building, the most statically exposed facade columns.

In this paper we pay attention to the composite steel-reinforced concrete structures.

Fig. 1. View on building during erection

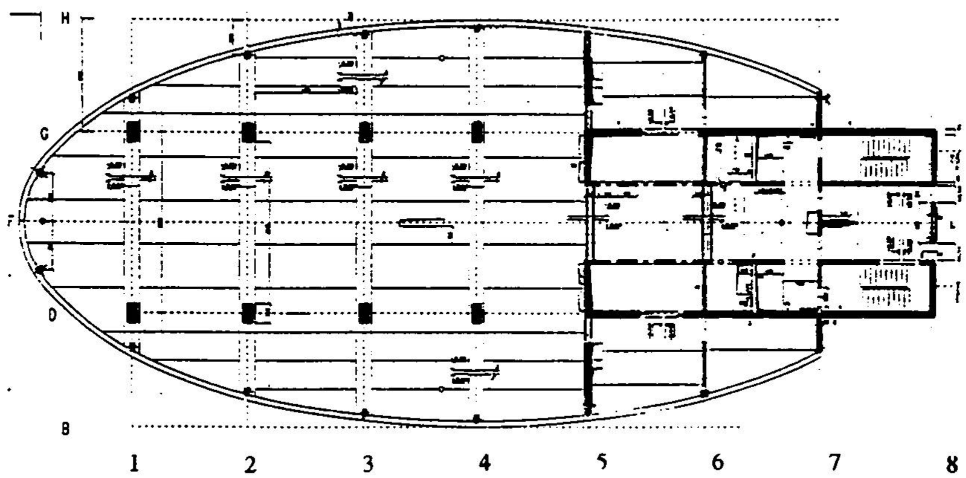


Fig. 2. Layout of typical storey

2.2 Composite inner piers

The inner piers in the ground floor are extreme loaded at axis 1 by an axial force of N_d = 26 800 Kn and in the axis 2 and 3 by N_d = 16 800 kN and demanded small dimensions of 1200/600 or 1000/500 mm respectively. If the need of structural clear seating of steel grid in transverse plate is respected, it is suitable to use for piers the composite steel-concrete form (Fig. 3). The piers have two welded I profiles which carry about 50% of designed normal force. The piers are boarded with a steel plate stiffened by vertical plates, the reinforcing bars are joint to them by welding. On the site were delivered the steel structures of piers included of reinforcing bars completed in two storey length.

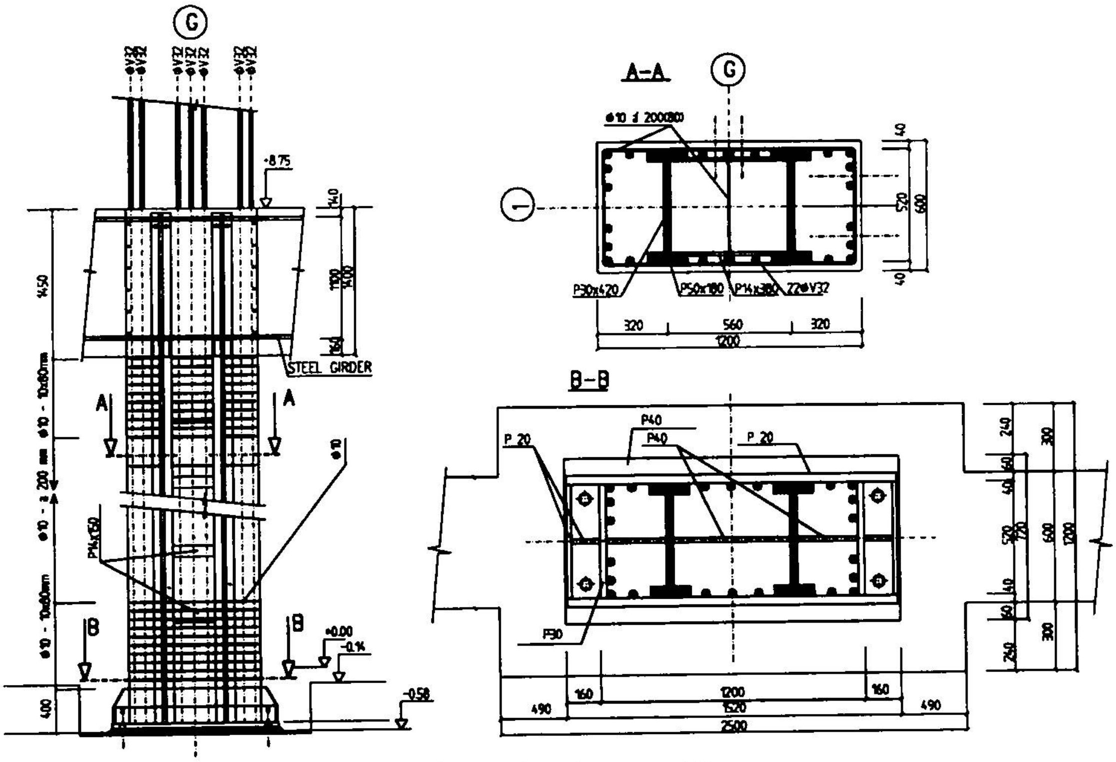


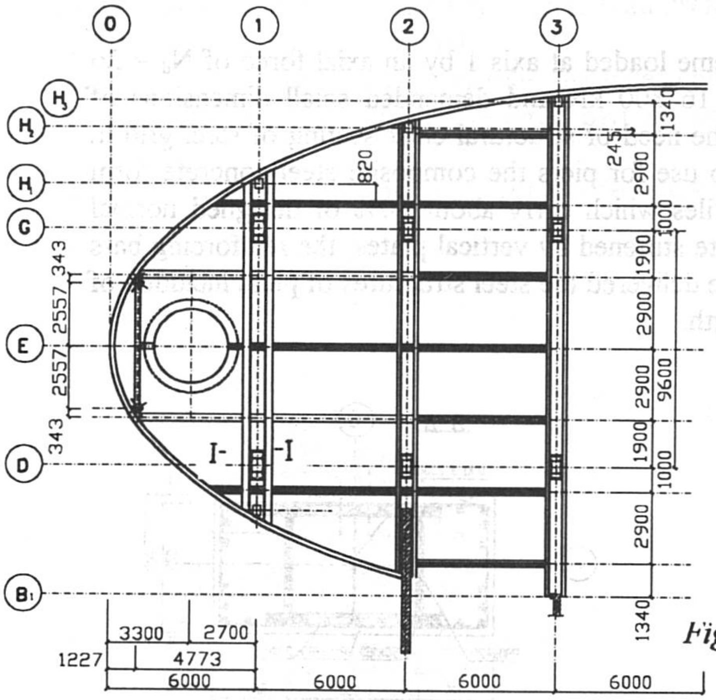
Fig. 3. Composite inner piers in ground floor

2.3 Cantilevered transverse steel-concrete plate over 2nd storey

Four facade columns situated in modulus 0 - 1 acting with normal forces about 5000 kN are based on the elliptical transverse plate. The statically exposed transverse plate demand the height of 1,20 ÷ 1,40 m, similar to the upper peripheral girders. The designed facade coating demands a very strong stiffness (the deflection of the top $y_{max} \leq 20$ mm, declination on the periphery tg $\chi \leq 0{,}0015$). The site and construction conditions were not good for prestressed r. concrete, therefore the following solution was elected (Fig. 4):

- steel grid of 1,10m height in two fields with 6 m cantilevered console, elliptical layout, seated on composite piers, built from transversal and longitudinal girders dimensioned on dead load of 1,40 m concrete slab
- precast lower plates of 90mm height suspended on the steel girders dimensioned on the 0,4 m concrete layer
- in-situ concrete with reinforcement bars concreted in two steps.

By this solution is achieved: quick construction tempo (no strong formweek, no technology break), precise geometry.



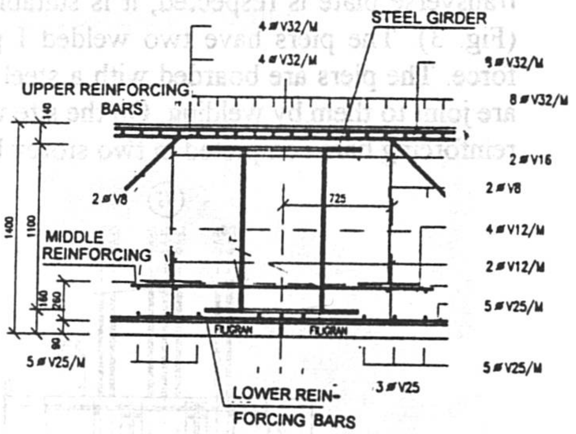


Fig. 4. Cantilevered transverse steel-concrete plate:

a - layout of steel grid, b - cross section

2.4 Precast facade columns

In spite of the normal forces in the columns varying from 1500 kN to 6200 kN the same rectangle size 30.40 m was elected.
The corresponding bearing capacity was achieved at constant total area $A=A_a + A_s + A_b$ by combination of six parameters (index b - concrete, s - steel reinforcement, a - steel profile)
The total compression capacity was determined

$$N_{tot} = N_a + N_s + N_b = (A_a R_a + A_s R_s + 0{,}85\ A_b R_b)\ \delta$$

where A-cross section area, R-design strength, δ-buckling factor (expressing the influence of slenderness and of imperfections and loading excentricity). The minimum compression capacity is achieved at cross section with constructive reinforcement (A_s = 0,006A), the middle one by higher quality of concrete and strong reinforcement and the max compression bearing capacity by addition of inner steel profile (Table 1).
The columns have been constructed as in shop prefabricated element. Most columns are of two storey length, fitted with short console for placing facade elliptical girders and crossing girders. The contact joint is solved by means of steel boarding plate and screws (Fig. 5).

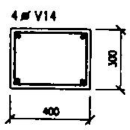
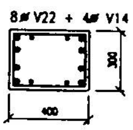
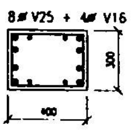
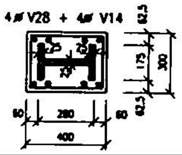
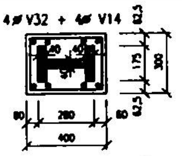
TYPE	CROSS SECTION	AREA [cm²]	R_i [N/mm²]	MATERIAL	RESISTANCE N_i [kN]	φ	N_{Rd} [kN]
S 150		A_a	R_a		N_a	0,803	1979
		A_s= 6,2	R_s= 375	O 10 425	N_s= 232,5		
		A_b= 1193,8	R_b= 22	B 40	N_b= 2626,5		
S 275		A_a	R_a		N_a	0,812	2881
		A_s= 36,6	R_s= 375	O 10 425	N_s= 1372,5		
		A_b= 1163,4	R_b= 22	B 40	N_b= 2559,5		
S 350		A_a	R_a		N_a	0,815	3642
		A_s= 47,3	R_s= 375	O 10 425	N_s= 1773,8		
		A_b= 1152,7	R_b= 27,5	B 50	N_b= 3169,9		
S 500		A_a= 145	R_a= 210	O 11 373	N_a= 3045	0,785	5005
		A_s= 24,6	R_s= 375	O 10 425	N_s= 922,5		
		A_b= 1030,4	R_b= 27,5	B 50	N_b= 2833,6		
S 610		A_a= 220	R_a= 200	O 11 373	N_a= 4400	0,785	6141
		A_s= 32,2	R_s= 375	O 10 425	N_s= 1207,5		
		A_b= 947,8	R_b= 27,5	B 50	N_b= 2606,4		

Table 1. Facade columns - cross section and compression capacity

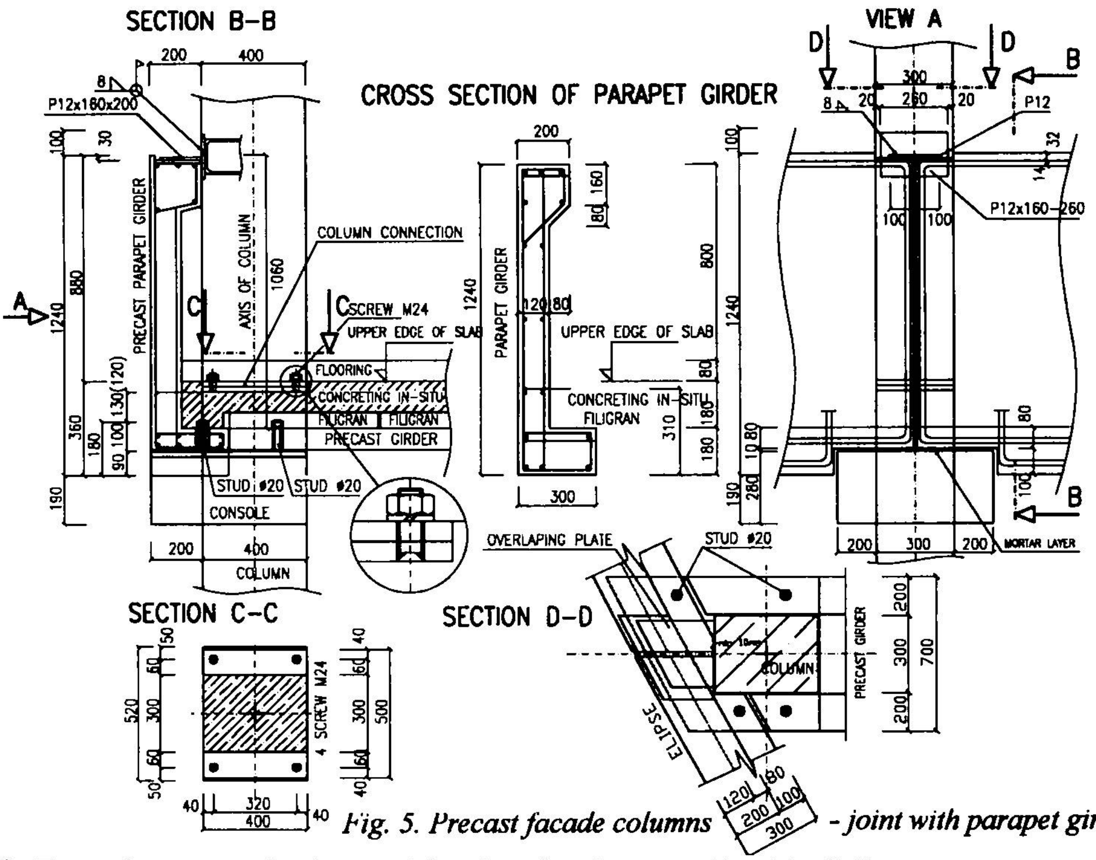


Fig. 5. Precast facade columns - joint with parapet girders

3. Experience results in combined technology realized building

After our experiences, we could summarise:

1. Combined structural system enables new architectural forms and realization technologies.
2. In comparison with complete steel solution: greater stiffness, rigidity and durability, simplified corrosion and fire protection, more structural complementation.
3. In comparaison with complete concrete structure: smaller dimensions of the bearing elements, higher mass of structures which could be prefabricated, more precise geometry, shortening the erection time (namely in comparison with in-situ concrete).
4. New technology, short tradition, not enough knowledge from edication process, structural designer obliged to know perfectly both materials.
5. Higher pretention on the coordination during the planning and realization.
6. The economical effects are in the region of indexes which are difficult to quantity - short time of realization, in the steel proper accuracy, clear static and structural system.

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