Recent Trends in Civil Engineering & Technology
Volume 1, Issue 1-3 Compilation 2011

Effect of Deck-Pylon Connection in Extradosed Bridges

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ABSTRACT

An extradosed bridge is characterized by very less values of the ratio of pylon height to main span of cable stayed bridges. The obvious advantages of extradosed bridges with span length less than 250 m compel to study various parameters in detail. In the present paper, an attempt has been made to study the effects of having different types of connections between pylon and deck girders. Effects of structural response such as pylon moment, girder moment, etc., have been studied in detail. The influence of seismic zone, static and geometrical nonlinearity has been studied on the effects of deck-pylon connections. Responses due to various live load patterns on extradosed bridges have been demonstrated.

Keywords: Extradosed bridges, geometric nonlinearity, seismic effects, stiffness-based FEM analysis

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INTRODUCTION

Over the past 10 years, extradosed bridges have become an attractive structural type around the world due to its aesthetic and effective structural system. An extradosed bridge is a bridge in which the steel cables, which are usually inside the girders, are anchored outside the girder enabling the cross section of the main girder to be made smaller than a regular girder bridge. The tower height is much lesser as compared with the tower of conventional cable-stayed bridge. Since last two decades, extradosed bridges are attracting the attention of designers. Extradosed bridge technology is adopted partly from externally prestressed girder bridges and partly from modern cable stayed bridges. An extradosed bridge is advantageous over conventional cable stayed bridge for bridge length less than 250 m. The live load stress is small in the case of extradosed bridge, leading to more compact pylon [1] especially in the case of fan type cable layout. Venkat, L [2] studied the optimum relative cost of extradosed bridge as compared to normal cable stayed bridge. It is concluded that for a bridge span of less than 250 m extradosed bridges are economical and beyond a span of 250 m, ordinary cable stayed bridges are economical. In the design of cable stayed bridges, the type of connection between the pylon and the deck can play a dominant role [1].

If the deck is (simply) supported on the towers, the induced seismic forces will be minimal, but the bridge may be very flexible under service loading conditions. On the other hand, a rigid connection between the deck and the towers will result in reduced movements under service loading conditions but will attract much higher seismic forces during an earthquake [3]. The integral connection of the deck with the pylon transfers the moments from the girders to the pylons, thereby reducing the design moments in the girder. At the same time, use of floating deck avoids the accumulation of stresses due to secondary effects like creep, shrinkage and changes of temperature, as well as due to seismic forces. Rao and Rao [4] studied the effect of support condition of pylon and deck-pylon connection on response of cable stayed bridges specific to seismic condition.

MODELING

In the present paper, two important types of connections have been studied (Figure 1). The various studies have been done to see the effect of deck-pylon connection. In the first case, linear analysis with static condition with uniformly distributed load has been considered as given in Table I. Maximum responses have been taken for each bridge length. Four live load patterns (Figure 2) have been taken to study the effect on deck bending moment and deck deflection. Extradosed bridges proved to be economical for the range of span lengths less than 250 m [2], hence study is conducted up to bridge length of 250 m only.

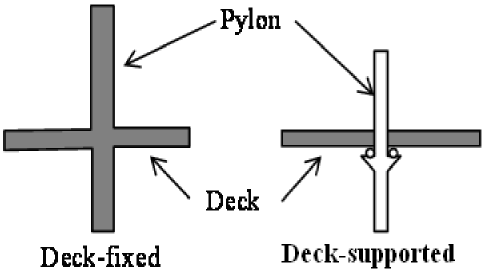


Fig. 1 Deck-Pylon Connection Details.

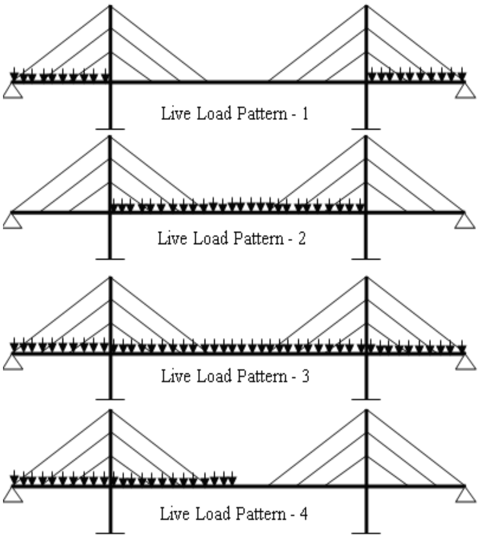


Fig. 2 Live Load Patterns on Bridge.

Table I Data for the Model.

No. of Cables		20
Dead Load		50 kN/m
Live Load		40 kN/m
Bridge Length		100–250 m
Unsupported Span-to-Main Span Ratio		0.3
Side Span to Main Span Ratio		0.45
Tower Height to Main Span Ratio		0.2
Cable	Area, A	0.005 m^2
	Young’s Modulus, E	1.5×10^{11} kN/m^2
Girder	Area, A	4.02 m^2
	Young’s Modulus, E	2.1×10^8 kN/m^2
	Moment of Inertia, I	2.631 m^4
Tower	Area, A	1.62 m^2
	Young’s Modulus , E	2.1×10^8 kN/m^2
	Moment of Inertia, I	0.9446 m^4

ANALYSIS

The analysis of cable stayed bridges taking into account their three dimensional behavior is a relatively complex problem. The optimization of such structures requires simplified approaches. Thus, if simplified assumptions are made with regard to boundary conditions of the bridge deck, the problem may be reduced to a two-dimensional analysis [5]. In the present work, the latter case, two-dimensional analysis, is carried out using stiffness method. Lute et al. [6] developed the stiffness based FEM analysis module for cable stayed bridges which can combine the module for optimization using the MATLAB platform. The bridge is assumed to be a plane structure. Deformations due to shear, torsion and warping of the section are neglected. The analysis of cable stayed bridge for the basic superimposed load and live load including self-weight is performed using stiffness method. For analysis, single plane is considered and the loads are assumed to correspond to the single plane. The superimposed dead load and live loads are taken in terms of uniformly distributed load.

The present approach considers three major geometric nonlinearities. Geometric nonlinearity is induced due to large displacements, due to cable sag, and due to beam-column effect in the deck and pylons [8, 9]. It has been proven experimentally as well as analytically that cable-stayed bridge response is nonlinear due to its inherently flexible nature [3, 8, 10]. In the present work, cables are assumed to have stiffness only in tension. An equivalent stiffness is used to account for cable sag and stiffening effects, wherein each cable is assigned a reduced modulus of elasticity depending on its inclination and cable tension. The large deformation effect has been applied by forming the equilibrium equations for each deformed position and with the help of virtual work principle the element tangent stiffness matrix K_{T_i} is obtained. The procedure adopted for beam-column-effect consideration is taken from Adeli and Zhang [11].

As for seismic analysis of cable stayed bridges, there are three different approaches. The time history analysis provides structural response as a function of time, but structural design is usually based on peak values of forces and deformation over the duration of the earthquake-induced response. In the response spectrum analysis (RSA) procedure, structures are excited by a single component of ground motion. That is, simultaneous action of the other two components is excluded and multiple support excitations are not considered [7]. In the present problem, the response spectrum analysis is carried out and the procedure has been explained with the help of a flow chart given in Figure 3. RSA is a procedure for dynamic analysis of a structure subjected to earthquake excitation, but it reduces to a series of static analyses.

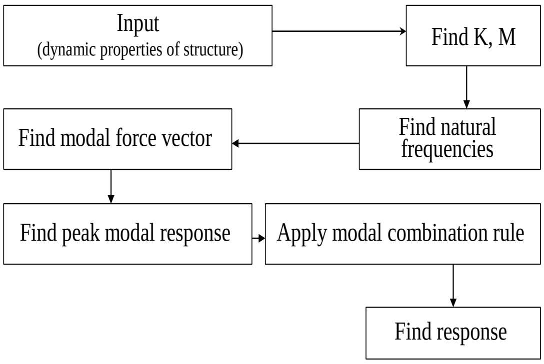


Fig. 3 Flow Chart for RSA.

Consideration of the flutter phenomenon is crucial in order to protect the structure from collapse. Hence aerodynamic stabilization against catastrophic flutter is highly important for cable stayed bridges. In order to handle such flutter problems, Lute et al. [12] developed a support vector based optimization program for conventional cable stayed bridges. In the present work, the influence of deck-pylon connection in extradosed bridges is studied under static and seismic loadings with due consideration to nonlinearities.

RESULTS AND DISCUSSION

The cable-stayed bridges with the data shown in Table I, are analyzed with various variations. Bridges having two types of cable stays (radial and harp types), located in two seismic zones are analyzed under both linear and nonlinear behavior. The maximum responses of the bridges are studied for two types of deck-pylon connections, viz., deck-fixed and deck-supported.

Static condition: Extradosed bridges (with radial type cable stays) of spans up to 250 m are analyzed under linear behavior with the two types of deck pylon conditions. Figure 4 shows a comparison of the maximum tower bending moments. It is observed from Figure 4 that for extradosed bridges having a bridge length of 250 m deck-supported simply will allow around 12% more bending moment in tower as compared to deck-fixed condition.

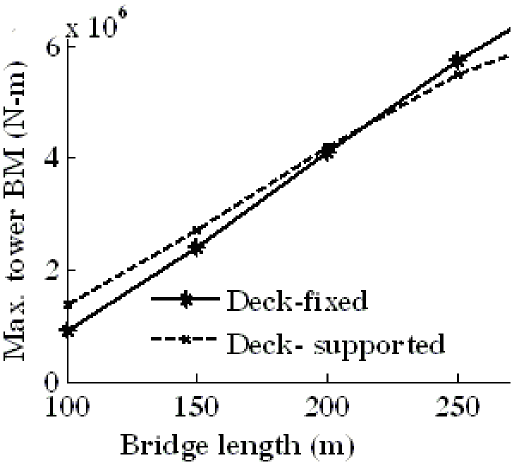


Fig. 4 Effect on Tower Moment.

From Figure 4, it is observed that there is a 5% increase in tower bending moment due to the deck fixed condition as compared to deck-supported condition.

Seismic condition: The same study has been conducted for seismic conditions for radial cable system. Two seismic zone factors, one with z = 0.24 and another with z = 0.36 are taken for studies. For each zone the maximum response in terms of deflections and bending moments in deck and tower are shown in Figures 7–11.

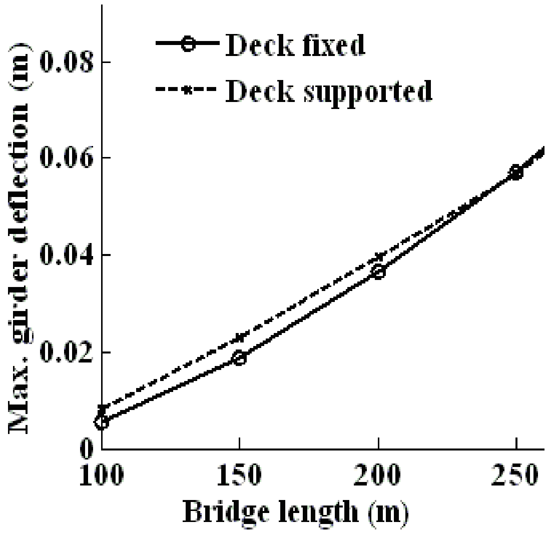


Fig. 5 Effect on Deck Deflection.

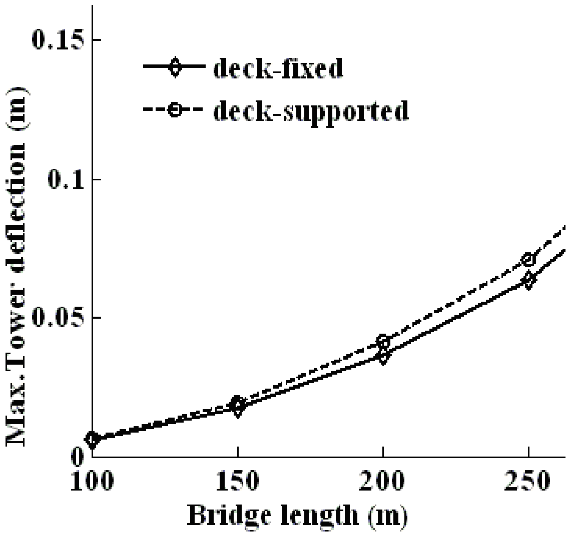


Fig. 6 Effect on Tower Deflection.

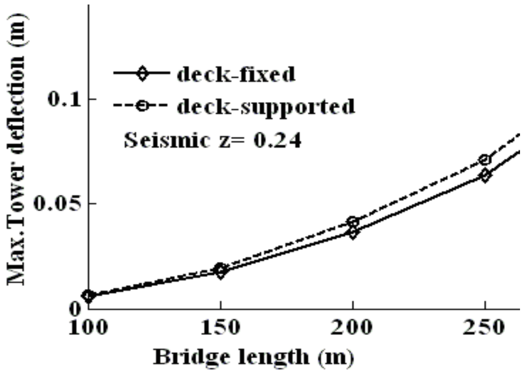


Fig. 7 Effect on Tower Deflection for z = 0.24.

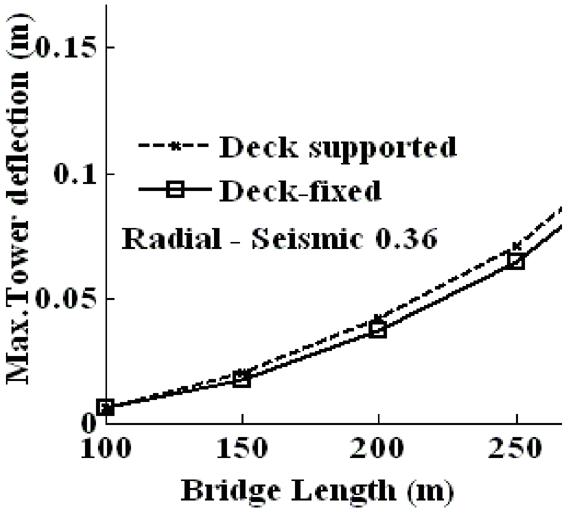


Fig. 8 Effect on Tower Deflection for z = 0.36.

It is observed that for a zone factor of 0.24 the difference in the maximum tower deflection for 100 m bridge is negligible and the maximum tower deflection is increasing up to 15% for span length of 250 m for deck-supported connection as compared to deck-fixed connection.

It is observed from the above study that for a radial cable system for zone factor 0.36 there is a difference of 12% in the tower deflection, the difference of 5% in the deck deflection and hardly any difference in the deck bending moment when deck-fixed and deck-supported are compared.

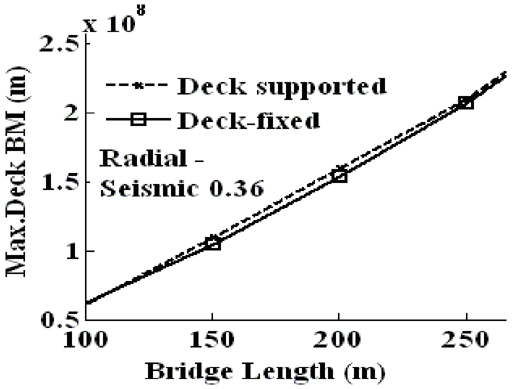


Fig. 9 Effect on Deck BM for z = 0.36.

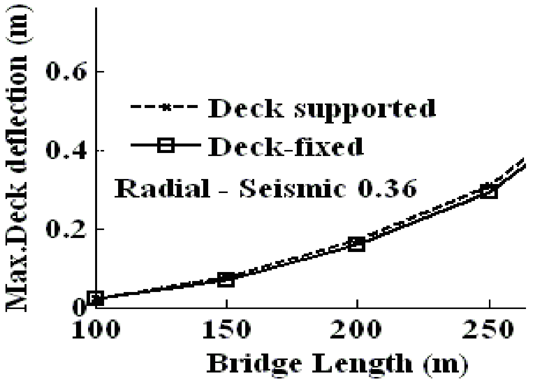


Fig. 10 Effect on Deck Deflection for z = 0.36.

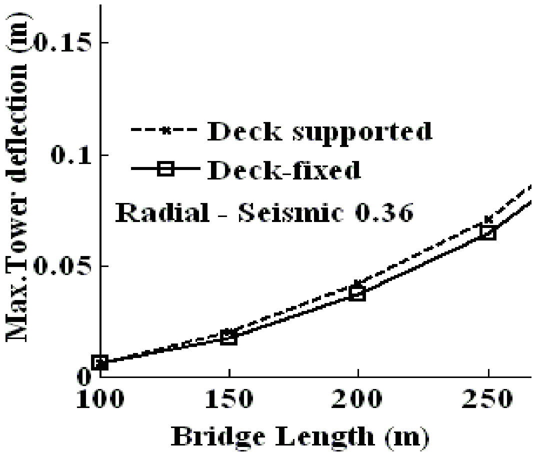


Fig. 11 Effect on Tower Deflection for z = 0.36.

Nonlinear condition: In the third part of the study, the bridge is analyzed considering non-linearity in the bridge. The three types of nonlinearities have been considered, i.e., nonlinearity with respect to cable sag effect, beam-column effect and large deformation effect. The effect of deck-pylon connection on maximum deflection in tower and maximum deflection in deck as well as on bending moment in tower and girder have been demonstrated using nonlinear analysis. These effects are shown in Figures 12, 13. From these Figures, it is clear that when the non-linear effects are considered,

- The maximum bending moment in deck/girder remains unchanged even if the type of connection of deck and pylon is changed.
- The maximum bending moment in tower changes drastically, when the type of connection between deck and pylon is changed.

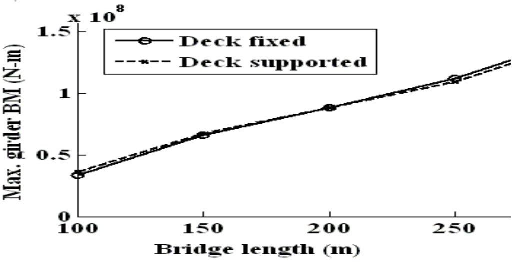


Fig. 12 Effect on Deck BM.

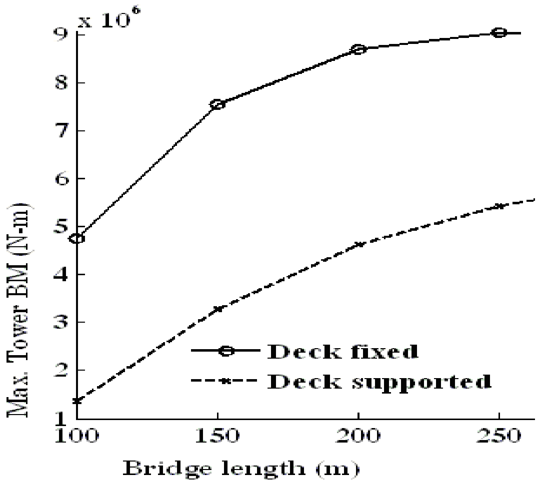
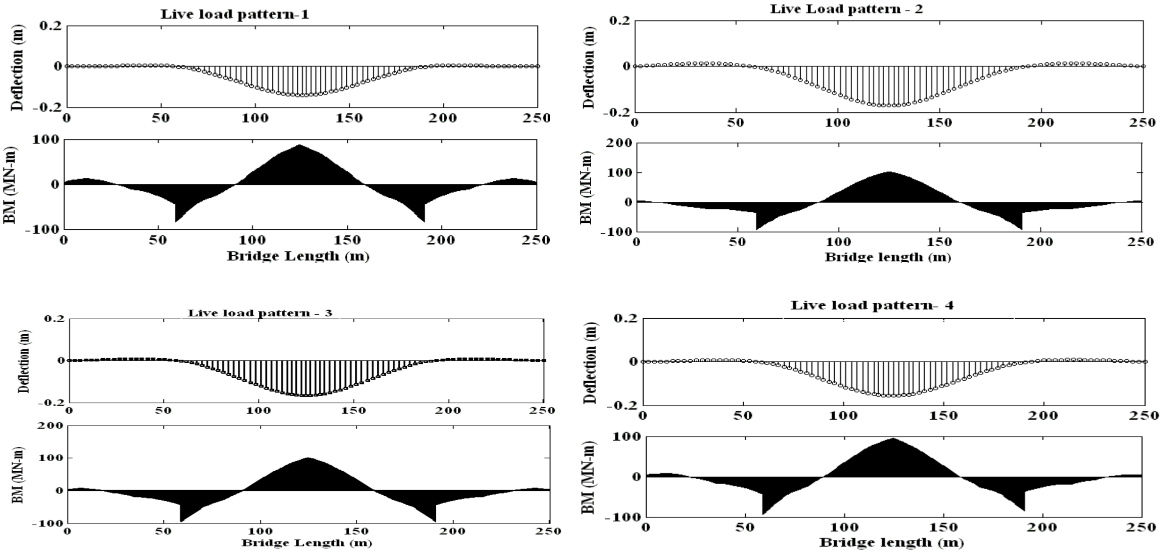


Fig. 13 Effect on Tower BM.

For studying the influence of live loads, the pattern loading strategy is adopted. As mentioned before, Figure 1 shows the live load patterns that are studied. The pattern loading response has been plotted to verify the behavior of the bridge. For this purpose, the deflection profile of deck and bending moment profile of deck are shown in Figure 14 for a typical extradosed bridge.



Live load pattern-1

Live Load pattern - 2

Live load pattern - 3

Live load pattern- 4

Fig. 14 Deck Deflection and Moments due to Live Load Patterns.

SUMMARY AND CONCLUSIONS

An extradosed cable stayed bridge is analyzed. The effect of connection between pylon and deck has been analyzed thoroughly due to the parameters such as seismic zones and nonlinearity. The effect of various live load positions on deck deflection have been demonstrated using the developed stiffness-based finite element program in MATLAB.

The conclusions drawn from this paper are as follows:

(i). The developed MATLAB program is especially beneficial for optimization of extradosed bridges by combining analysis module with optimization module.

(ii). Effect of deflection in the tower is increasing as bridge span increases. For a span length of 250 m for linear analysis, the deck-supported connection will yield to 12% more deflection in tower as compared to deck-fixed connection. The deck-fixed connection gives 5% more bending moments in tower, and for the span of 200 m there is no difference between two connections as far as tower bending moment is concerned.

(iii). Effect of seismic zones on extradosed bridge has been studied. Two zone factors, 0.24, and 0.36 were used for demonstrating their effect on deck-pylon connection. Tower deflection is 15% more for a deck-supported condition for span length of 250 m for z = 0.24. Similarly, for zone factor 0.36 maximum of 12% increase in the tower deflection, 5% increase in deck deflection and hardly any difference in the deck bending moment for deck-supported connection is observed.

(iv). The study of the effect of nonlinearity on deck-pylon connection demonstrates that 60–90% change in the tower bending moment can occur due to change in deck-support condition. In the case of deck bending moment, there is hardly any difference in two types of deck-pylon connections.

REFERENCES

1. Mathivat, J. FIP Notes. 1988(2). 15–21p.
2. Venkat, L. Genetic Algorithm Based Optimum Design of Cable Stayed Bridges. *PhD thesis*. 2009. Indian Institute of Technology Roorkee, (India).
3. Nazmy, A.S. and Abdel-Ghaffar, A.M. *Computers & Structures*. 1990. 34(2). 257–271p.
4. Rao, P.V., and Rao, P.S. *International Conference on Current Trends in Aqueducts*. Road. Rail and Marine Bridges. Hyderabad (India). December 20–22, 2005. 145–170p.
5. Lazar, B.E. *Journal of Structural Division*. Proceedings of ASCE. 98(ST7). 1971. 1605–1611p
6. Lute, V., Upadhyay, A., and Singh, K.K. *Journal of Artificial Intelligence in Engineering Applications*, ELSEVIER 45. 2009 (a). 750–758p.
7. Chopra, A. K. *Dynamics of structures: Theory and Applications to Earthquake Engineering*. 2nd Ed. Englewood Cliffs, NJ. Prentice Hall. 2004.
8. Ali, H.M. and Abdel-Ghaffar, A.M. *Computers and Structures*. 1995. 54(3). 461–492. 1995p.
9. Fleming, J.F., and Egeseli, E.A. *Earthquake Engineering and Structural Dynamics*. 8, 1980. 1–16p
10. Abdel-Ghaffar, A.M. and Nazmy, A.S. *Journal of Structural Engineering*. 1991.117(11), 3456–3476p.
11. Adeli, H. and Zhang, *J. Computers and Structures*. 1995. 54(2). 267–277p.
12. Lute, V., Upadhyay, A., and Singh, K.K. *Journal of Advances in Engineering Software*. ELSEVIER. 2009 (b). 40. 830–835p.