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VII

Interactive and Automated Design of Cable-Stayed Bridges

Projet de ponts à haubans à l'aide de l'ordinateur

Interaktive und automatisierte Vorbemessung von Schrägseilbrücken

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SUMMARY
This paper presents the outline of the concept and application of the computeroriented design system, TOPCAB. This system is primarily used for the preliminary design of cable-stayed bridges. Through the use of TOPCAB an approximate steel weight based on the optimum prestresses in cables and stiffness of girder-cable is promptly obtained.

RESUME
L'article présente une aperçu général de la conception et de l'application du système TOPCAB. Ce système sert essentiellement au projet préliminaire de ponts à haubans. Le poids d'acier approximatif peut être obtenu sans difficulté au moyen du système TOPCAB, sur la base de la précontrainte optimum des câbles et de la rigidité des câbles de poutres.

ZUSAMMENFASSUNG
Das Konzept und die Anwendung des Bemessungssystems TOPCAB werden gezeigt. Dieses System wird hauptsächlich für die Vorbemessung von Schrägseilbrücken, die im modernen Stahlbrückenbau eine wichtige Rolle spielen, verwendet. Mit Hilfe von TOPCAP wird das ungefähre Stahlgewicht unter Berücksichtigung der optimal vorgespannten Kabel und der Steifigkeit der Trägerkabel schnell ermittelt.

1. INTRODUCTION

The present paper deals with the computer use in the structural design considering the main title of Thema(VII) "Computer Analysis and Structural Engineering" in the introductory report of the 11th congress of IABSE.(1)
The authors have engaged in the development of the large scale computer-oriented system in the design and fabrication of steel bridges since 1973(5).
The present TOPCAB system(4) is the finally developed computer-oriented design system in the total project including the formerly developed structural optimization techniques(2)(3) and automated drawings, etc.
The total process for the design of cable-stayed bridges is a multistage procedure which ranges from consideration of overall system requirements down to the detailed design of individual components. In the analysis and design of cable-stayed bridges the use of computers is always essential. The development of matrix structural analysis programs has enabled detailed structural analysis of any type of cable-stayed structure appearing in modern bridges.
In the planning design of the cable-stayed bridges the arrangement of the cables in the longitudinal direction of the bridge may vary according to the designer's sense of proportion of clear spans and tower heights. In this stage the designer needs the many design-oriented information to make the best decision among the given choices.
In this paper outline and results of interactive and integrated large scale system named TOPCAB are presented. TOPCAB is conveniently used for the preliminary design, but the modules of input generator and structural analysis are also applicable to the final design.

2. ORGANIZATION OF THE ENTIRE SYSTEM

Since the completely automated design of large system is suffering from inflexibility when faced with the various designer's requirements, interactive and conversational systems are employed for the data generation and structural optimization.
TOPCAB is mainly divided into four basic subsystems and each module of the subsystem and database are controlled by the TOPCAB supervisor. The organization of TOPCAB is illustrated in Fig. 1. The input and output data are generated in the TOPCAB database under the control of the supervisor. This database structure is convenient as input data source and also a media through which many modules exchange data and make a consistent design. All TOPCAB commands and available program names are stored in a relational data structure for easy information restration and efficient data management. The entire system is designed to be interactive by using the database with relational data structure and the graphic terminal.

3. BASIC FUNCTIONS OF TOPCAB

An integrated system for the design of cable-stayed bridges is organized by making full use of four subsystems provided by TOPCAB. The primary function of each subsystem is outlined as follow.

3.1 Data Generation

For a given bridge span, many variations and combinations of the cable arrangements in the longitudinal direction and the tower elevations can be considered as shown in Fig. 2. If you want to get the design information for all combinations of the types, it is tedious and time consuming to make input card decks in the usual structural analysis.
The structural member data in the longitudinal direction and the transverse direction of any cable-stayed bridges can be generated by using 16 commands with 39 parameters and 5 commands without parameter. Any structural data can be generated by the translation and computation of these commands. TOPCAB has another facility to prepare the database from graphic terminal in demand mode

as shown in Fig. 3. Input data generator is developed to minimize the input data for structural analysis.

3.2 Structural Synthesis

The optimization concept and technique can be used to obtain the initial design-oriented information. Since the designer must make a best choises based on the economic evaluation, he wants to obtain the economic information of considerable type of cable-stayed bridges before beginning the final design. The optimality parameter method (2) is used for the optimization of cable-girder structural system. The newly developed visualized optimization technique using graphic terminal is also applicable to the stress arrangements of cables. Structural optimization technique is also applied to determine the basic dimension and the material combination of steel tower section shown in Fig. 4. Thus the approximate steel weight is promptly computed by full use of the available capabilities of TOPCAB.

3.3 Structural Analysis and Design

The available structural analysis programs in TOPCAB are mainly based on the matrix displacement method. Nonlinearity behavior of the structure can be also considerable by the utility of TOPCAB. The design standard used in the system is "Specifications for Steel Highway Bridges (Japan Road Association)".

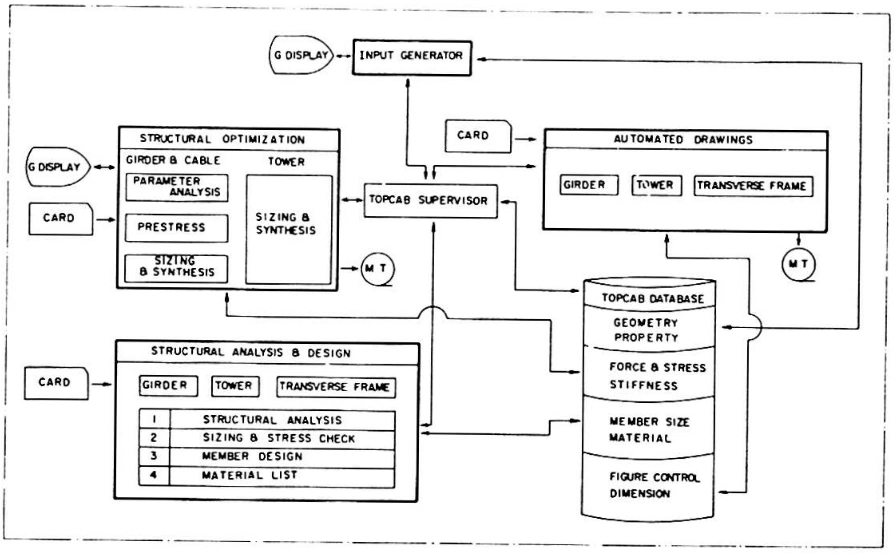


Fig. 1 Organization of the Entire System

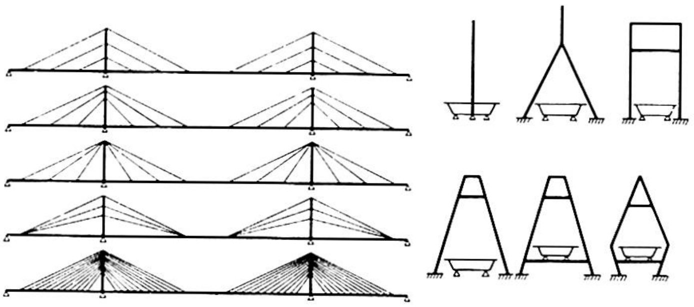


Fig. 2 Variety of the Elevation

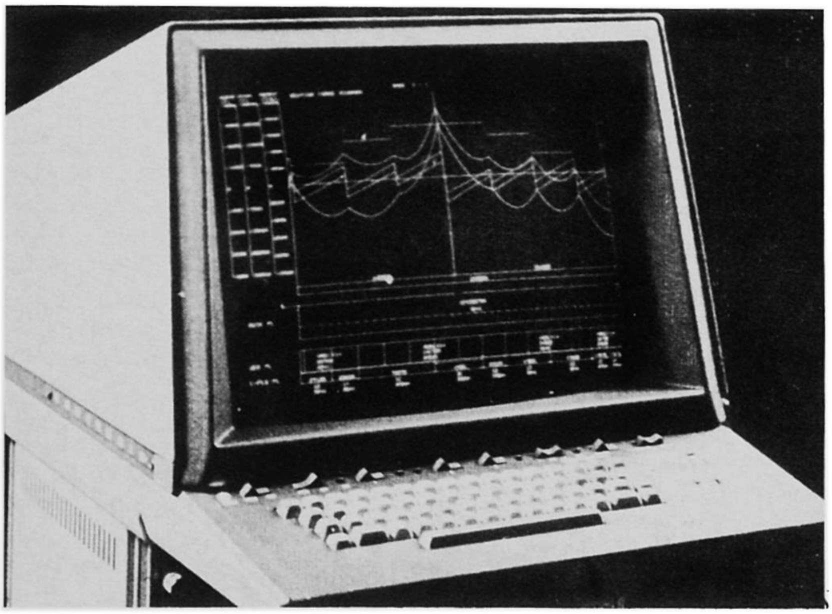
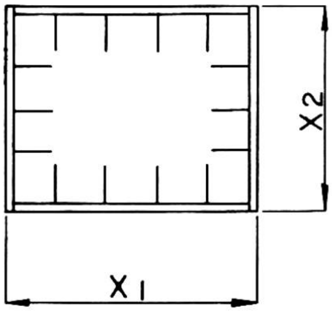


Fig. 3 Graphic Terminal

3.4 Automated Drawing Facilities

Automated drawing facilities can be applied to the drawing of trapezoidal shaped main girder, transverse frame, and tower. The automated drawing facilities are used to make the more accurate economic evaluation in the early design stage by accounting the steel weight of detail member (splice plates, stiffening plates etc.).



1 SS41
2 SM50Y
3 SM58
4 HT70
5 HT80

Fig. 4 Tower Frame Section

4. APPLICATION OF TOPCAB

The primary purpose of developed TOPCAB is to provide the designers with practical tools in the preliminary design stage of cable-stayed bridges. Two resulting examples of the application to the actual models are presented herein.

4.1 Optimization of the Prototype Model

Basic bridge section and tower elevation of the analytical model are shown in Fig. 5. Basic side elevation and five different cable arrangements in the longitudinal direction are shown in Fig. 6. The basic dimension of the bridge is very similar to the Yamato River Bridge now under construction in Osaka Prefecture Japan.

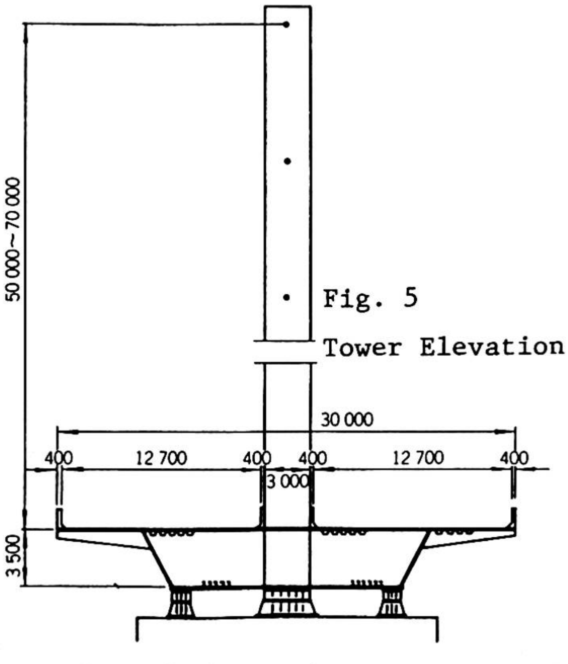


Fig. 5 Tower Elevation

Results of the optimization are given in Table 1. In this study the optimum structural system based on the minimum weight design is the harp type with triple cable arrangements.
The section force due to the dead load and live load is shown in Fig. 7.

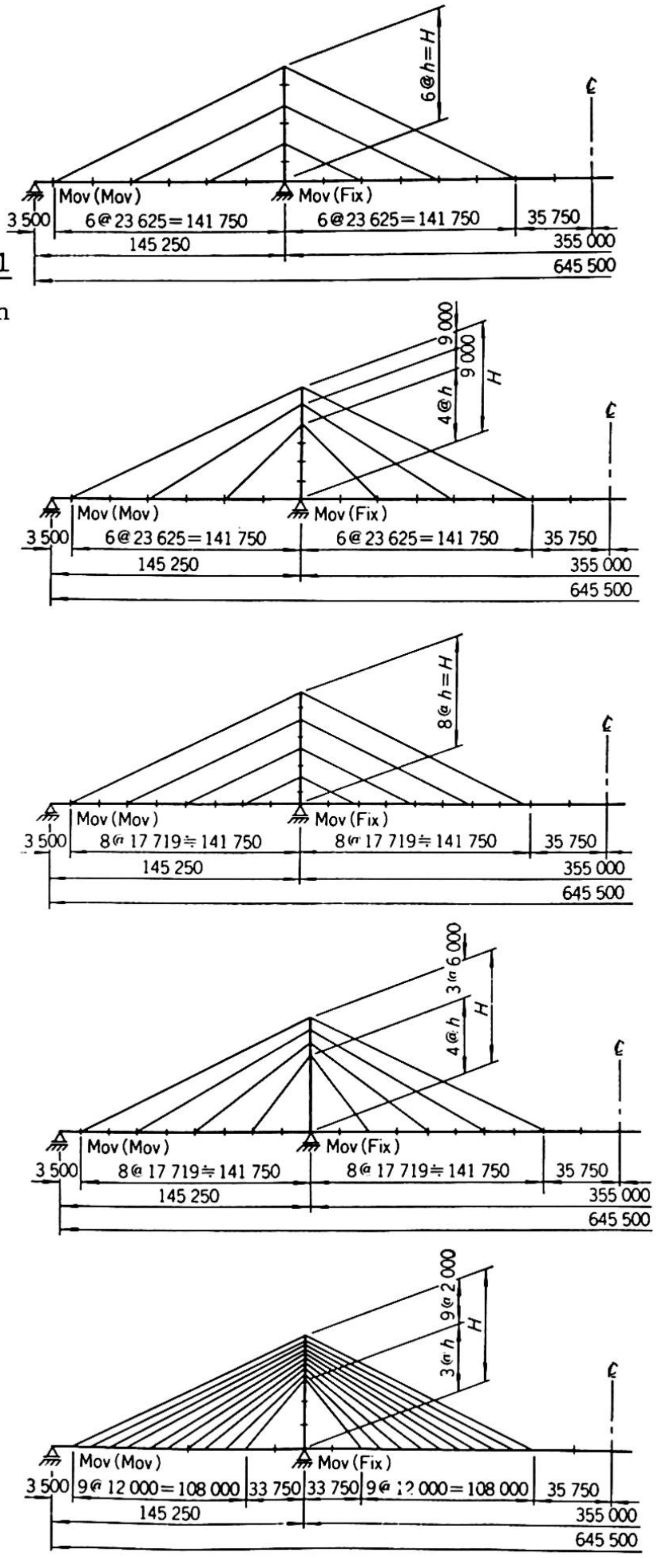


Fig. 6 Cable Arrangements

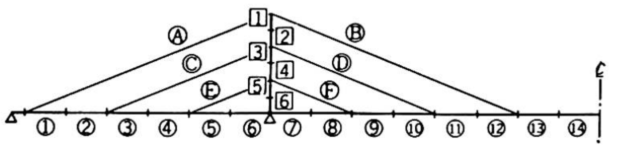
The optimum prestresses in this structural system are given in Fig. 8, and the section force arranged by the optimum prestresses is also drawn in Fig.7. These section forces and girder sections can be drawn by either the graphic display terminal or high speed NC drafter.

Table 1 Results of Optimization

CABLE TYPE		TOWER HEIGHT	APPROXIMATE STEEL WEIGHT							
			GIRDER (ton)		CABLE (ton)		TOWER (ton)		SUMMATION (ton)	
			MAIN	ETC.	CABLE	ETC.	SM58	HT70	SM58	SM70
HARP	3-CABLE	50 m	4 860	2 040	780	340	670	590	8 690	8 610
		60	4 830	2 040	710	340	930	820	8 850	8 740
		70	4 840	2 040	640	340	1 230	1 150	9 090	9 010
	4-CABLE	50	4 900	2 040	830	340	670	590	8 780	8 700
		60	4 840	2 040	760	340	900	810	8 880	8 790
		70	4 830	2 040	690	340	1 200	1 120	9 100	9 020
FAN	3-CABLE	50	4 830	2 040	770	340	770	680	8 750	8 660
		60	4 820	2 040	690	340	1 080	980	8 970	8 870
		70	4 830	2 040	670	340	1 390	1 330	9 270	9 210
	4-CABLE	50	4 800	2 040	830	340	730	650	8 740	8 660
		60	4 820	2 040	760	340	1 080	980	9 040	8 940
		70	4 830	2 040	730	340	1 380	1 320	9 320	9 260
	MULTI	50	4 840	2 040	970	340	740	660	8 930	8 850
		60	4 850	2 040	840	340	1 090	990	8 160	9 060
		70	4 830	2 040	830	340	1 380	1 330	9 420	9 370

4.2 A Drawing Example by NC Drafter

After completion of the member sizing, all digital data are stored in the TOPCAB database as the input source for the sequential automated drawings, and then the automated drawings are carried out. Fig. 9 and Fig. 10 are drawing examples of the actually completed Toyosato Bridge Osaka Japan.



Section Force Diagram Stiffening Girder

★ : SM50Y

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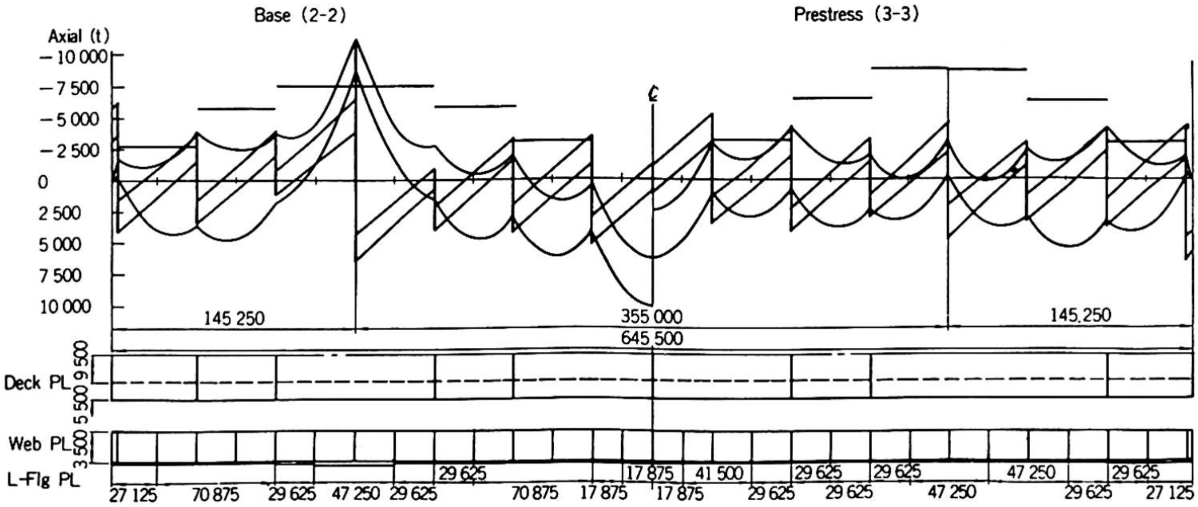
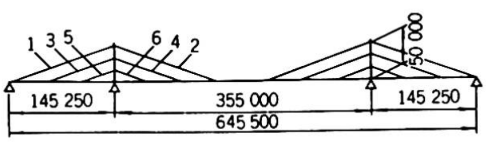


Fig. 7 Section Force Diagram and Basic Girder Section

5. CONCLUDING REMARKS

The authors formerly developed the large scale integrated design system for steel I-girder bridges and fabrication system using NC equipment. Those systems are now successfully used in the design offices and fabricating shops. TOPCAB was developed by the structural engineers and system engineers engaged in the former project.

TOPCAB system can be conveniently used for the preliminary design of cable-stayed bridges since the cable-stayed bridge is one of the most sophisticated bridge structure appearing in modern bridges and it require the multi process of complicated computer using structural analysis.



NO.	PST	D + L + PS (t)	PWS-217
1	170	3 655	23
2	170	3 551	23
3	400	3 224	19
4	400	3 354	19
5	700	2 453	15
6	700	2 503	15

Fig. 8 Optimum Prestresses

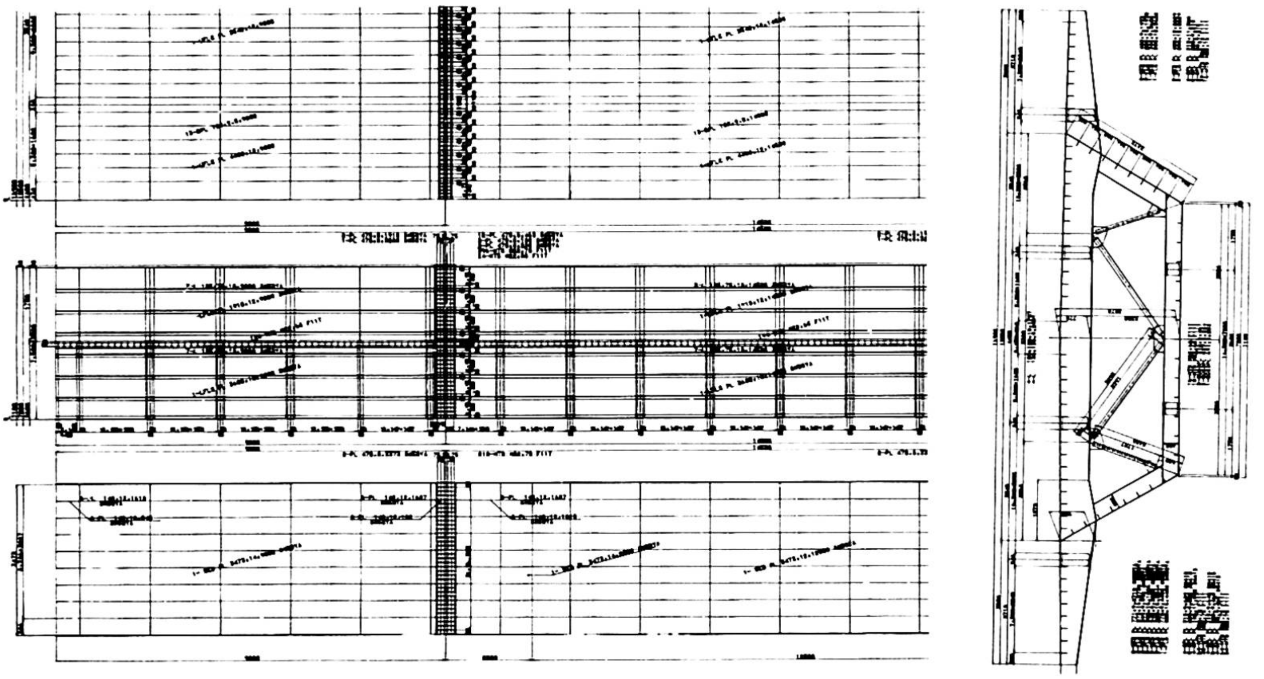


Fig. 9 Automated Drawing Example of Stiffening Girder

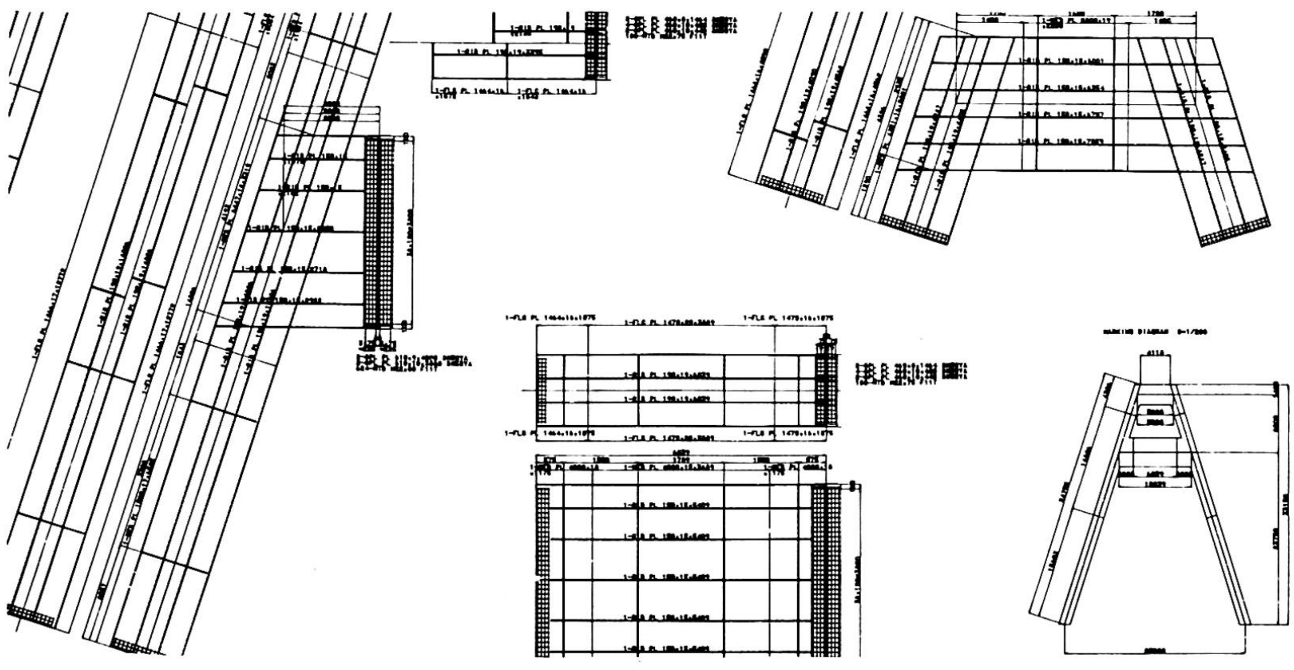


Fig. 10 Automated Drawing Example of Tower

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