Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 80 (1999)

Artikel: Monitoring of lateral earth pressures on well foundations through instrumentation
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DOI: https://doi.org/10.5169/seals-60748

MONITORING OF LATERAL EARTH PRESSURES ON WELL FOUNDATIONS THROUGH INSTRUMENTATION

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Summary

A major project involving extensive instrumentation of a large well foundation has been carried out at the recently completed Ganga Bridge at Varanasi. The instrumentation is intended for long-term monitoring of the design parameters for such large foundation wells. One of the wells has been instrumented with earth pressure cells, inclinometer and vibrating wire rebar load gauges. The earth pressure data obtained over a period of five years since the well was sunk to its founding level, along with the inferences drawn therefrom are presented in the paper.

1.0 INTRODUCTION

In the context of the currently acute need for scientific monitoring of the health of major bridges and for creating a reliable data base for their efficient management, the construction of the Ganga Bridge at Varanasi presented a unique opportunity to comprehensively instrument both its superstructure and substructure and monitor its performance from inception. This opportunity was utilised to plan and execute a major project aimed at long-term performance monitoring of the bridge through instrumentation.

The project involved, interalia, extensive instrumentation of the major components of the bridge viz. the superstructure, the pier, the pier head and the well foundation. A large number of structural parameters such as strains, deflections, slopes, tilts, thermal gradients, earth pressures etc. were continuously monitored during the construction of the bridge and would continue to be monitored for a few years during its service life. The data so obtained is expected to shed light on its short-term and long-term behaviour.

Of particular interest in this project was the instrumentation of one of the foundation wells of the bridge, since field data relating to the design parameters of such large well foundations is solely lacking. The instrumentation scheme for foundation wells including the parameters to be monitored and the corresponding instrumentation techniques used were described in earlier papers [1,2,3]. The details of installation of the sensors, the devices used for protecting the sensors and their cables during concreting and sinking operations and the data obtained during certain intermediate stages of construction were also described therein. The present paper, while touching briefly upon some of these aspects, presents an analysis of the data relating to the earth pressures on the well recorded since the well was sunk to its founding level.

2.0 SCOPE OF THE PROJECT

The general arrangement of the bridge is shown in Fig.1. The bridge deck is a twin-cell box girder with a deck slab supporting a 19.6m wide, 4-lane carriageway. The box girder cantilevers to 65.75m on either side of the pier in the main spans. The foundations for the piers of the main spans are 65m deep reinforced concrete wells with inside and outside diameters of 8m and 13m respectively. The region of the bridge marked for instrumentation at Pier P7 is also highlighted in Fig.1.

3.0 INSTRUMENTATION OF THE FOUNDATION WELL P7

The most important parameters which are critical to the structural design and stability of foundation wells and which are amenable to direct measurements are the lateral earth pressures at the soil-well interface, the tilt and shift of the well and the actual strains within the body of the well. Current design procedures for well foundations are predicated upon a number of assumptions relating to these parameters, particularly for large and deep wells as in the present case. A knowledge of the actual values of these parameters would throw considerable light on the validity of the

design assumptions and on the true structural behaviour of the well and the level of safety inherent in the current design procedures.

The design and performance parameters of foundation wells which thus call for in-situ measurement and monitoring, together with their corresponding instrumentation techniques are summarised in Table 1. These techniques imply that a well would have to be instrumented at several levels throughout its height. These ideas formed the basis of the instrumentation of well P7.

TABLE 1. Parameters Monitored and Corresponding Instrumentation Techniques used in the Well P7

Parameter	Technique
- Soil Pressure on the well	- Vibrating Wire [VW] Earth Pressure Cell
- Strain in concrete/reinforcement	- VW Rebar Load Gauge [RLG]
- Inclination of the well	- Inclinometer System

Fig.2 shows the three levels at which the instruments and sensors were installed in the well while Fig.3 shows schematically the typical layout of the instruments at a level. A summary of the final status of instrumentation of the well P7 is provided in Table 2. The instrument readings were recorded at several stages during the construction and sinking of the well. Evidently, at each stage a different set of conditions obtained with respect to the height of the well constructed, the extent of sinking, the position of the instruments vis-a-vis the water and bed levels. These data for some of the intermediate positions of the well were obtained while the well was still under construction and were presented earlier [3]. The data obtained after the well reached its founding level are presented and analysed in this paper.

TABLE 2. Final Positions of Instruments in Well P7

Instrument Level [IL]	RL [m]	Height above cutting edge [m]	Depth below bed level [m]	Type and Number of instruments installed
1. IL-1	19.15	24.15	30.15	- Inclinometer Casings [2 Nos.] - Earth Pressure Cells [6 Nos.] - 12 mm Rebar Load Gauges [6 Nos.]
2. IL-2	29.15	34.15	20.15	Same as IL-1
3. IL-3	39.15	44.15	10.15	Same as IL-1

4.0 MEASUREMENT OF EARTH PRESSURE ON THE WELL

From Fig.3, it is evident that the lateral earth pressure on the well is being measured with the help of VW pressure cells installed along the external face of the well as shown in the figure. At each of the three instrumented levels in the well, six pressure cells were installed symmetrically, at intervals of 60 degrees, starting from the longitudinal bridge axis. These positions from 0 to 300 degrees are termed IP 1 to IP 6, respectively. The earth pressures were recorded on different dates, starting from the day on which the well was finally sunk to its founding level, viz. from 7 January 1994. Fig.4 shows the distribution of lateral eath pressure around the well at the lowermost instrument level viz. IL 1. Fig. 5 shows the lateral earth pressure history at IL 1. Fig.6 shows the progressive variation in lateral earth pressure distribution along the height of the well at three instrument positions viz. IP 1, IP3 and IP5 for the same dates as in Fig. 4. Figs. 4, 5 and 6 are typical for all the three levels of instrumentation and instrument positions.

5.0 INFERENCES DERIVED FROM FIELD DATA

A massive amount of data has been obtained from the instruments installed in the well P7. This data is currently being analysed and would be eventually compared with the corresponding analytical results. However, the broad inferences that can be derived from the field data with reference to Figs. 4,5 and 6 are given below :

(i) In general, at all the three instrument levels, the pressures around the well obtained shortly after the well reached its founding level have shown a continuous decrease over a six month period, the maximum decrease of pressure at any one instrument position during the six month period being about 8 to 10 %

(ii) The pressure distribution around the well is quite uniform at the lowermost instrument level IL 1. (Fig.4). The pressure distributions at levels IL 2 and IL 3 however, show a marked deviation from uniformity, with a sharp increase of pressure values at one or two instrument positions. The deviation is particularly sharp at instrument position IP 1 and is much greater at level IL 2 than at level IL 3 . The increased pressures at IP 1 could possibly be attributed to the surcharge pressure exerted by the land mass which rises sharply a few metres away from the the edge of the water, along the river bank adjoining the well P7.

(iii) Fig. 5 indicates the variation in earth pressure right from the time of installation of the pressure cells, through a three year period after the well was constructed. The pressure history of Fig. 5 is typical of all the levels and indicates that the earth pressure on the well from the time it reached its founding level has been almost uniform and has stabilised over the years.

(iv) The earth pressure distribution along the height at all the six instrument positions, remained virutally unchanged throughout the period of construction of the pier.

(v) The pressure distribution along the height of the well at each of the six instrument positions viz. IP-1 to IP-6, on the same dates as in Fig.4 shows an almost linear variation of pressure along the height, except at IP-1 and IP-6. (Fig.6.)

6.0 CONCLUSIONS

For the first time, a large foundation well of a major bridge has been instrumented and its structural parameters monitored from the construction stage onwards. The work involved was indeed voluminous, with a very large number of activities to be performed to a strict time schedule e.g. planning of the scheme, procurement of equipment, installation of instruments at site etc. In spite of the arduous and hazardous site work involved it was gratifying to be able to implement the programme of instrumenting one of the largest well foundation for a bridge. The site data together with the collateral analytical work are expected to provide a basis for a more realistic assesment of the design parameters for such foundation wells.

7.0 ACKNOWLEDGEMENTS

The project would not have seen the light of the day without the sponsorship and financial assisstance of the Roads Wing of the Ministry of Surface Transport [MOST], Govt. of India, New Delhi. The valuable input and guidance in planning and implementation of the scheme received from MOST is also gratefully acknowledged.

The authors would like to acknowledge the cooperation and assistance provided by the U.P.P.W.D. as well as by the contractors viz. M/S Hindustan Construction Company. The authors would also like to gratefully acknowledge other scientific & technical staff of SERC[G] for their untiring efforts in the execution of this instrumentation project.

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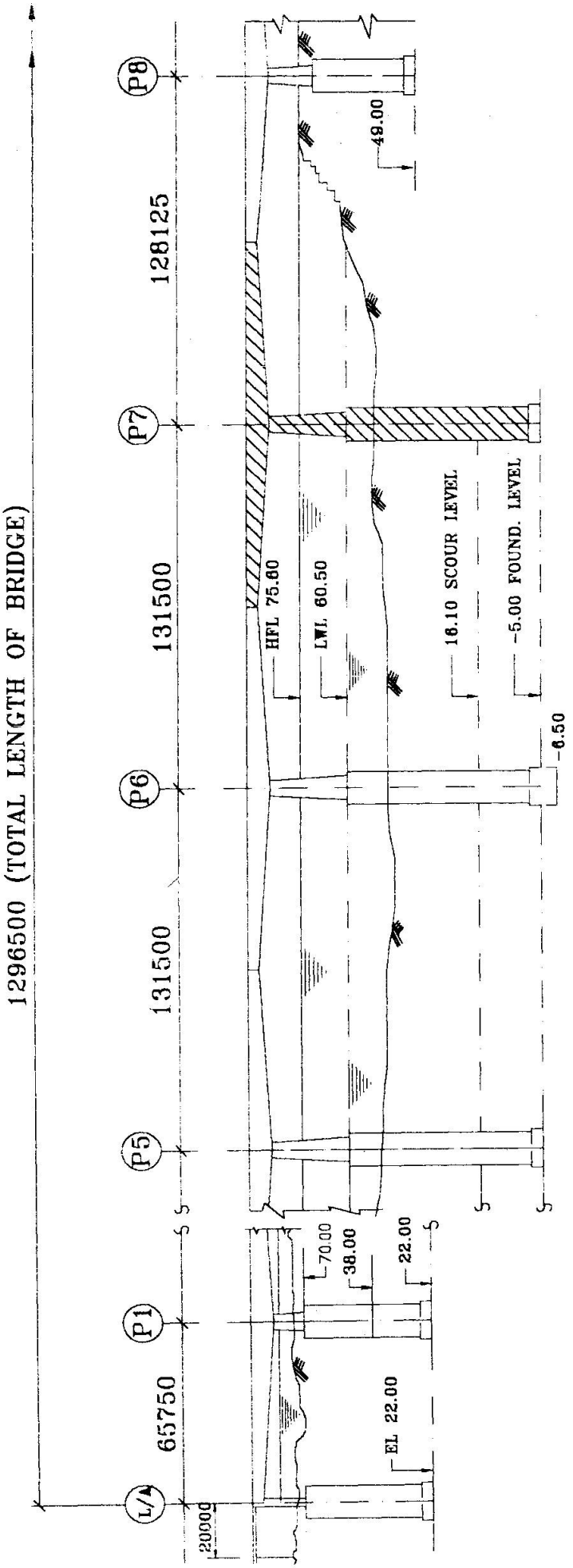


FIG.1 GANGA BRIDGE AT VARANASI: GENERAL ARRANGEMENT

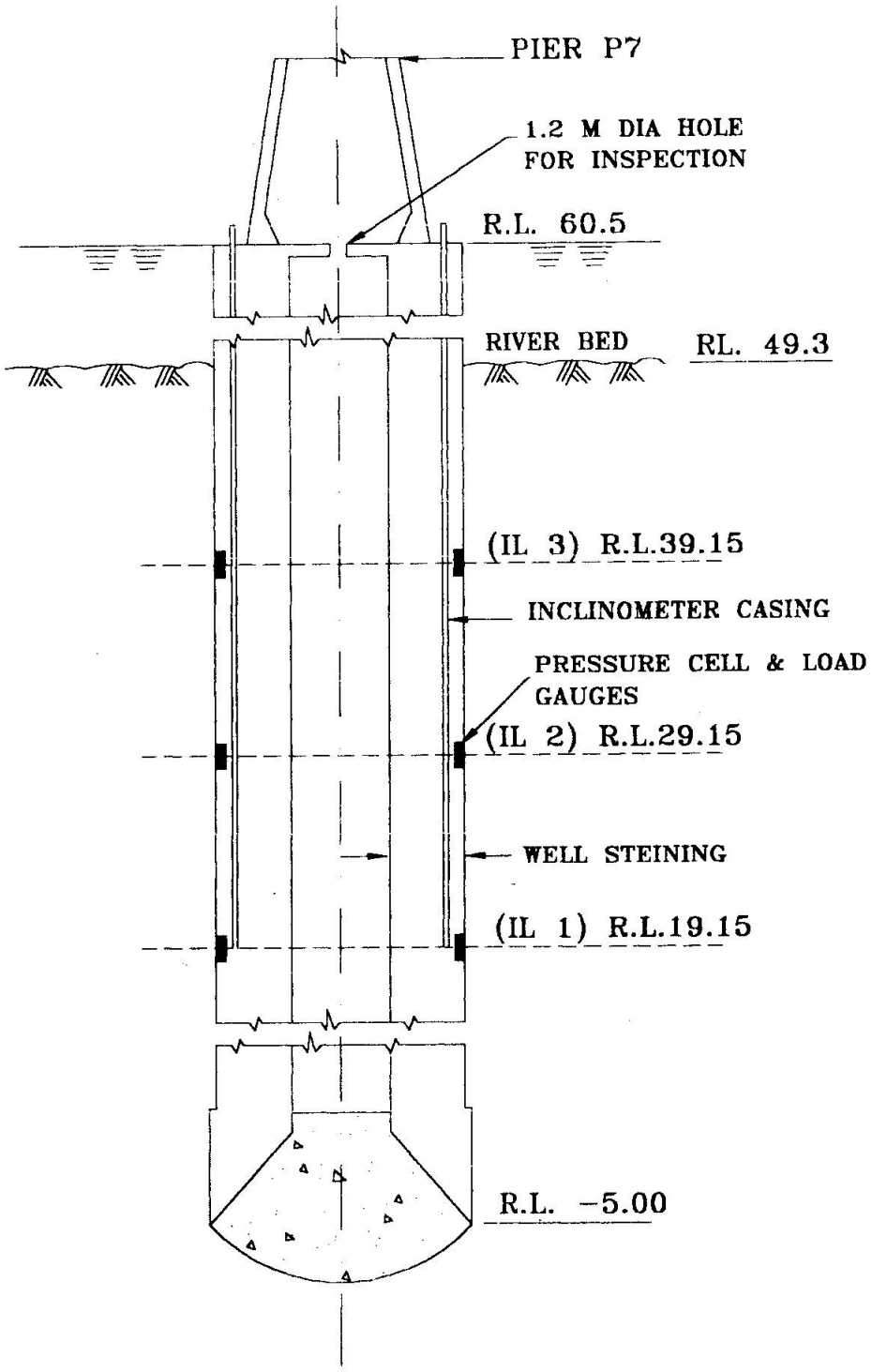


FIG.2 INSTRUMENTATION LEVELS (IL) OF WELL P7 (SCHEMATIC)

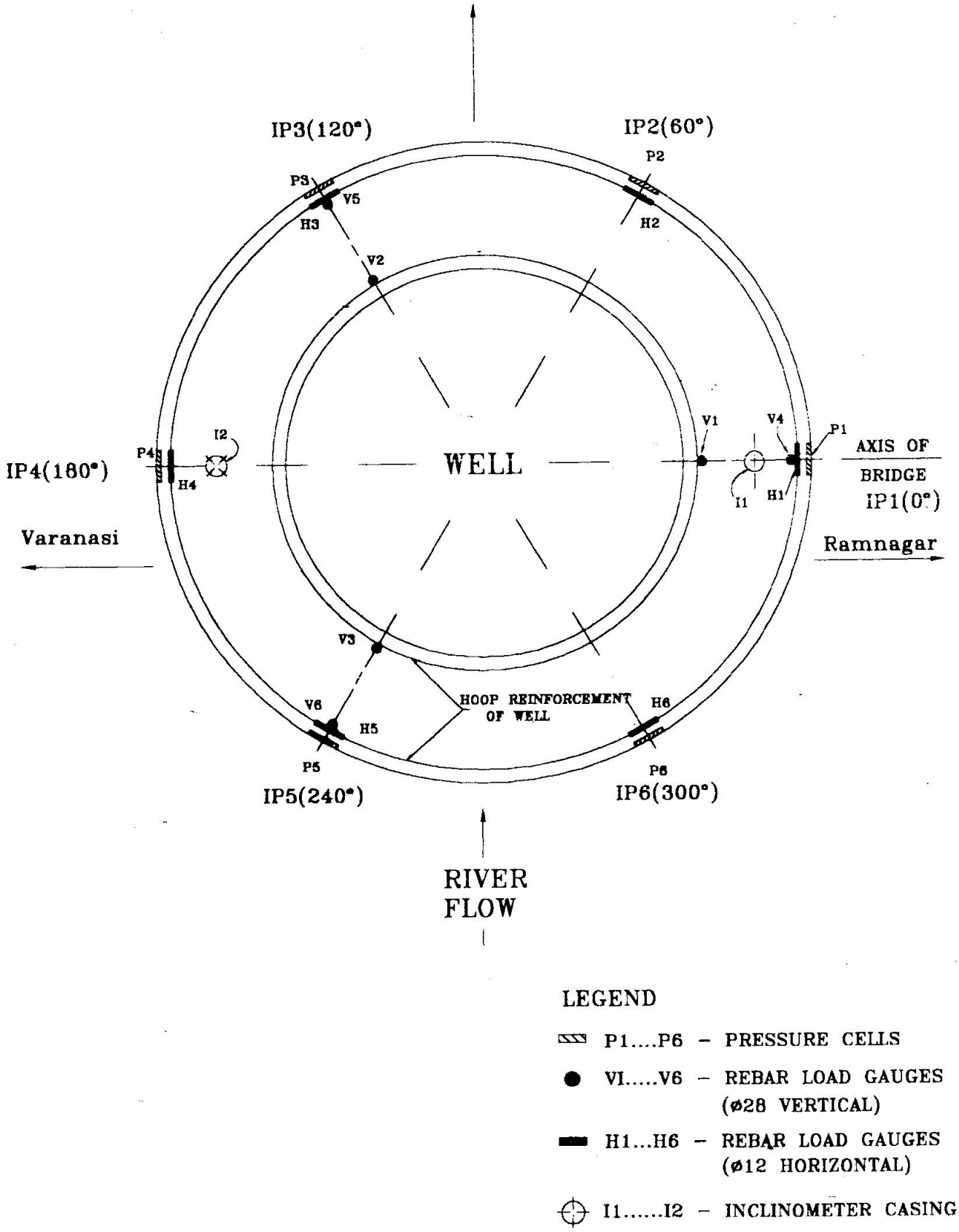


FIG.3 TYPICAL INSTRUMENTATION SCHEME AT A LEVEL IN WELL P7

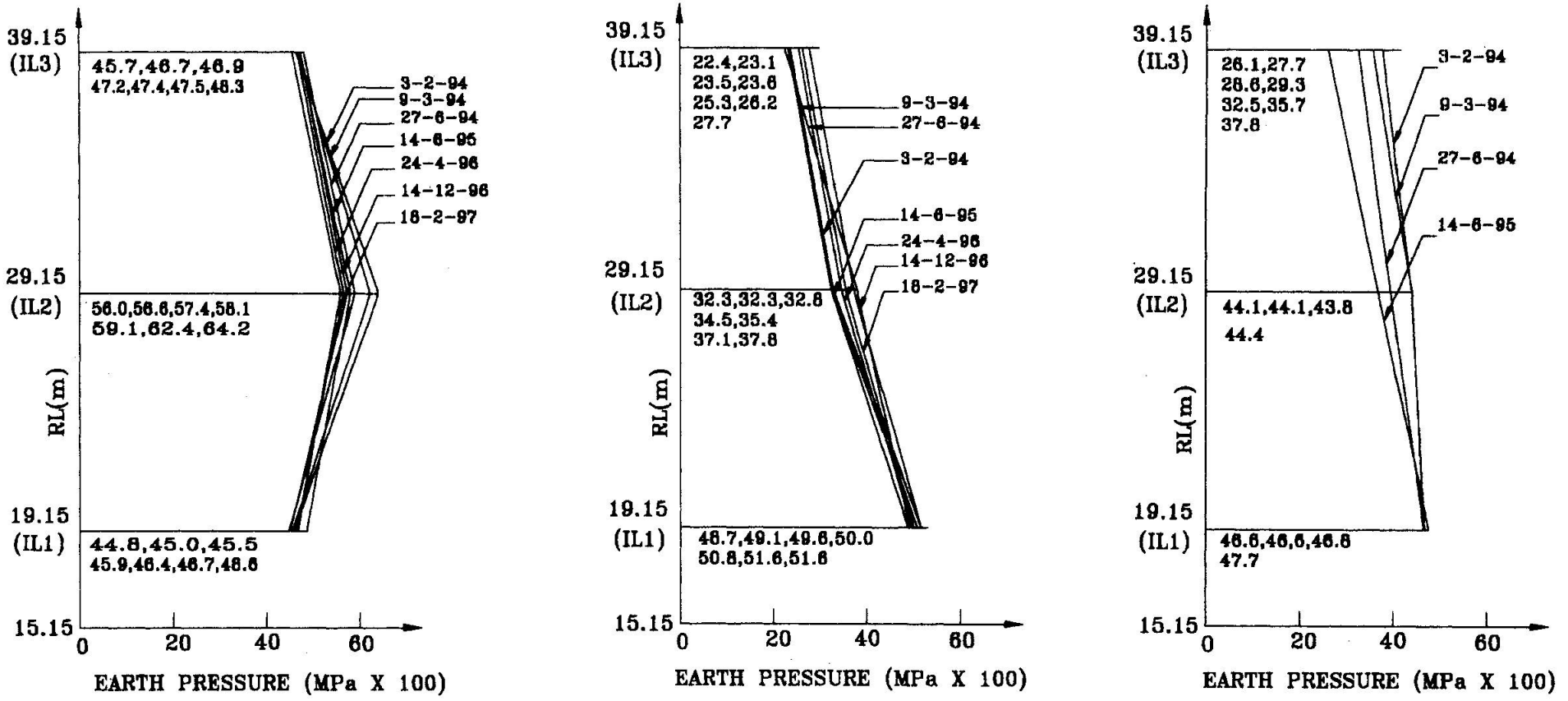
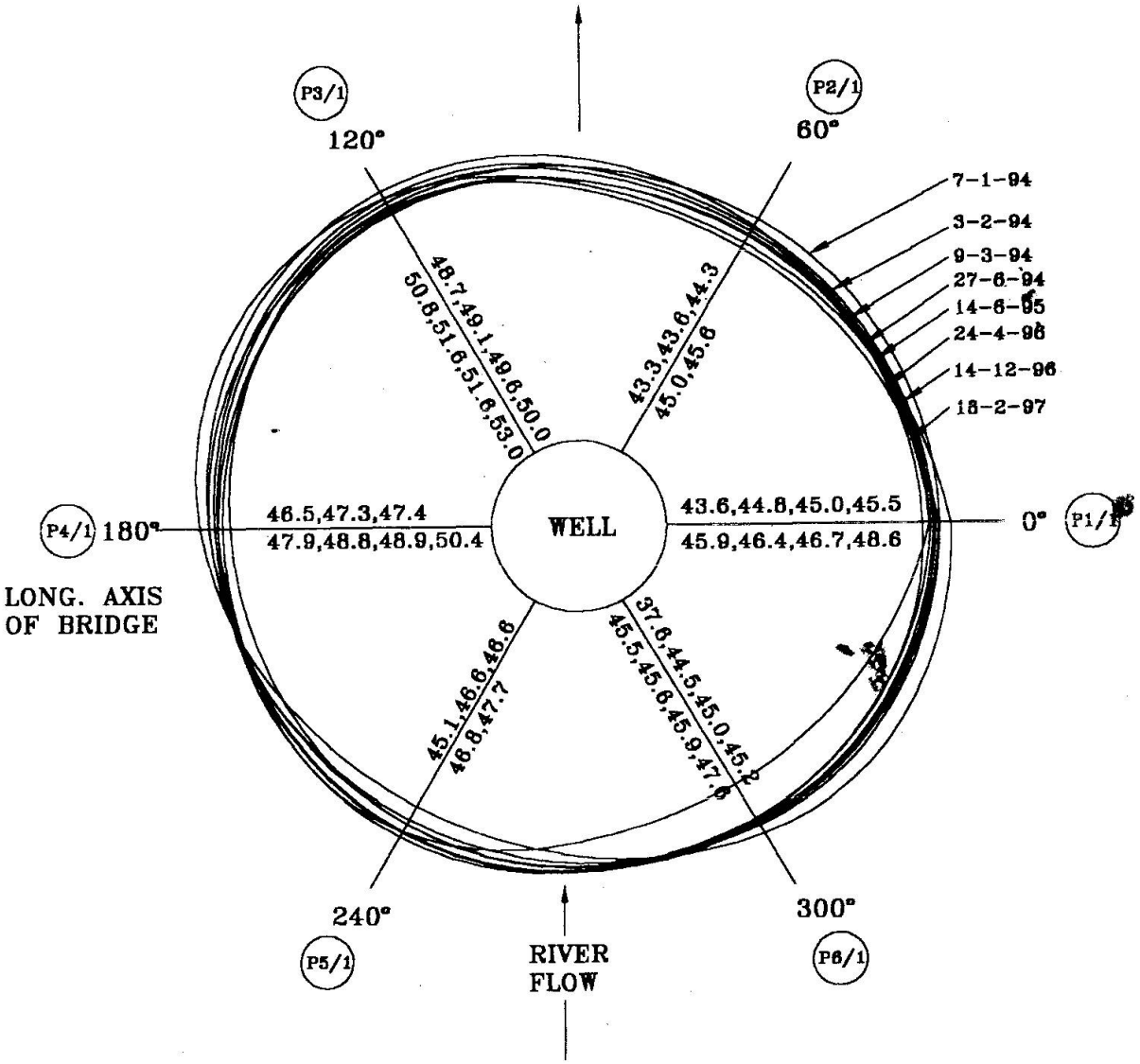


FIG.6 PROGRESSIVE VARIATION IN LATERAL EARTH PRESSURE DISTRIBUTION ALONG THE HEIGHT OF WELL P7



NOTES: 1.EARTH PRESSURE VALUE
ARE IN MPaX100

2. P6/1.... PRESSURE CELL NO. 6 AT IL-1

FIG.4 PROGRESSIVE CHANGE IN LATERAL EARTH PRESSURE DISTRIBUTION AROUND WELL P7 AT IL-1 AFTER REACHING FOUNDING LEVEL(TYP.)

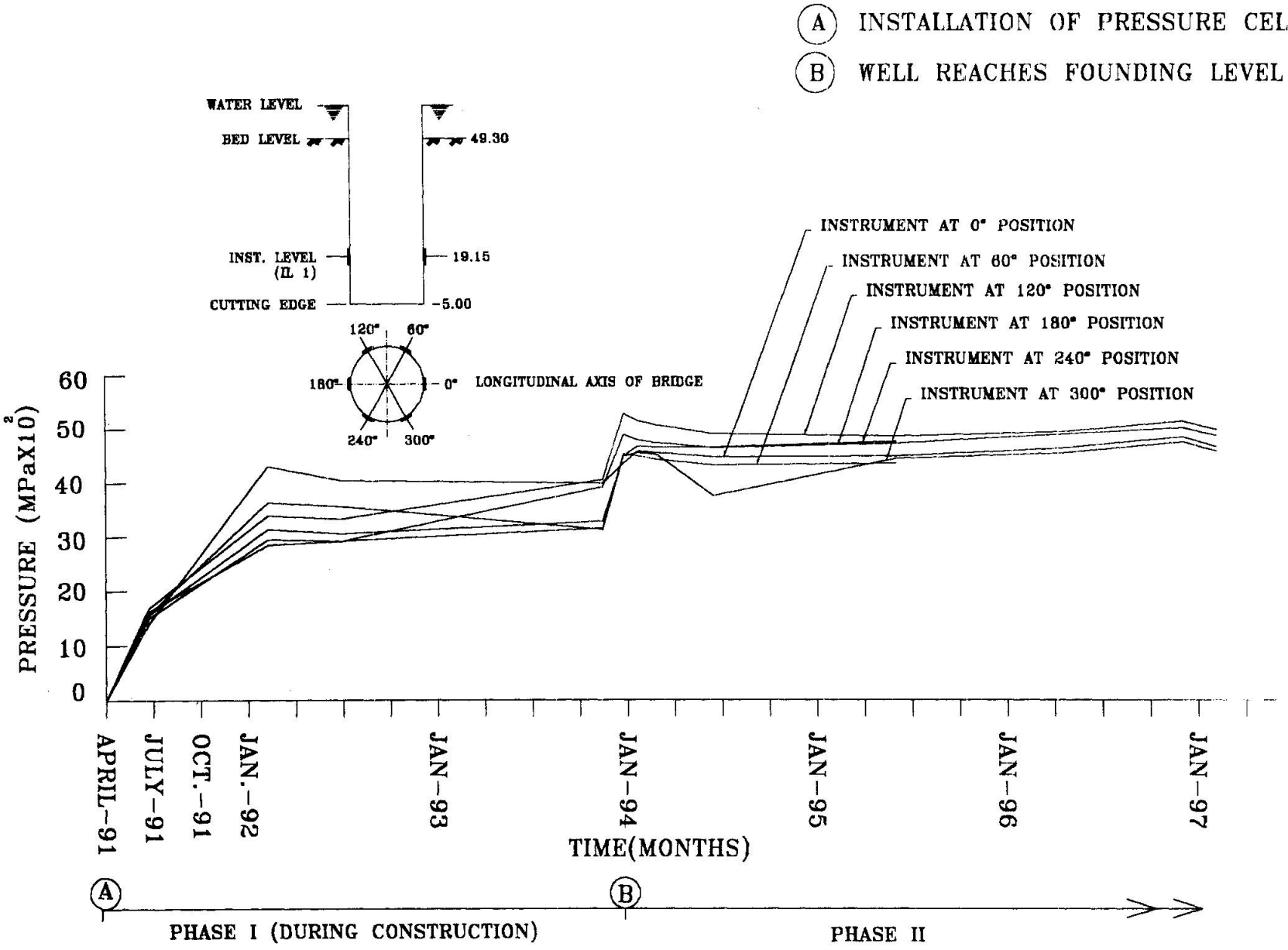


FIG.5 LATERAL EARTH PRESSURE HISTORY AT IL-1 (TYP.)

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