Analysis and Observation of Funchal Airport Extension

XU Min	L.OLIVEIRA SANTOS	J. ALMEIDA FERNANDES
Doctor	Assistant Research Officer	Director Research Officer
LNEC	LNEC	LNEC
Lisbon, Portugal	Lisbon, Portugal	Lisbon, Portugal

ABSTRACT

The main results of the observation during the final load tests, and the theoretical interpretation of the structural behavior by numerical models are presented for Funchal Airport Extension.

KEYWORDS

Funchal Airport, observation, load tests, strain, displacement

1. INTRODUTION

The Funchal Airport, on Madeira Island, was built in 1964 with a total runway length of 1600 m. Between 1982 and 1986 the Safety Project was carried out, extending the physical limits of the runway till 1800 m. Last years a new extension, which increased the runway from 1800 m to 2781 m, was executed. The new runway started service on 15 September 2000 (Fig.1).

The structure of the new extension has been instrumented during construction and its behavior has been experimentally followed during construction and in a final load test. In this paper the observation plans adopted and the main results obtained in the load tests are described. The paper presents only a small part of the large number of results obtained from the observations and the calculations performed.

2. STRUCTURE OF THE RUNWAY EXTENSION

The runway extension is an high bridge with 1000 m lengths by 178 m widths. The extension was carried out in two phases of construction: the first one with 546 m lengths and the second one with 457 m. There are structural joints between the old structure, the 1st phase and the 2nd phase extensions.

The extension structure consists of a succession of 32 m spaced frames which support a platform at 60 m high above mean sea-level (m.s.l.). The reinforced concrete slab, bi-directionally prestressed, has a thickness varying from 1.70 m, near frames, to 1.00 m, at its center span. Each frame is made up a succession of 6 columns aligned at square angles to the axis of the runway. These columns, with a maximum height of about 50 m are, 32 m distant from each other and support transversal beams with a variable cross section. These beams are 5.60 m high near columns, 3.60 m at the span center, and its underside is a parabolic curve. The column section is circular with a constant diameter of 3.0 m (Figure 2).

Figure 1. Panorama of the runway of Funchal Airport

Figure 2. The runway extension in construction

3. OBSERVATION DURING AND AFTER CONSTRUCTION

The structure has been instrumented with equipment to measure linear and angular displacements, strains and temperatures [SANTOS et al, Feb and Sept. 2000]. In each phase were instrumented 3 frames and 5 slab panels. The distribution of the equipment in the structure is exemplified in figures 3 and 4.

For long time measurement of vertical displacements, high precision levels are adopted. During the load test recording deflectometers are also used. For the measurement of joint movements steel bases are insert in concrete being accurately measured by a mechanical strain gage (deformeter). To measure the rotations of columns LNEC type bases were installed for readings with Huggenberger type air-bubble clinometers. The strain measurements were performed with vibrating-wire strain meters. About 500 strain meters were used for measure strain in the structures. The thermal gradients can cause significant stress variations in the structure. To obtain the thermal gradients in large cross sections resistance thermometers were placed across the thickness of the slab and the beam (figure 6). The evaluation of time effects in concrete – creep and shrinkage - is made based on measurements of the deformation of specimens placed over the deck in several sections with same conditions of the structure (figure 9).

In this way the structure's behavior has been experimentally followed during and after construction.

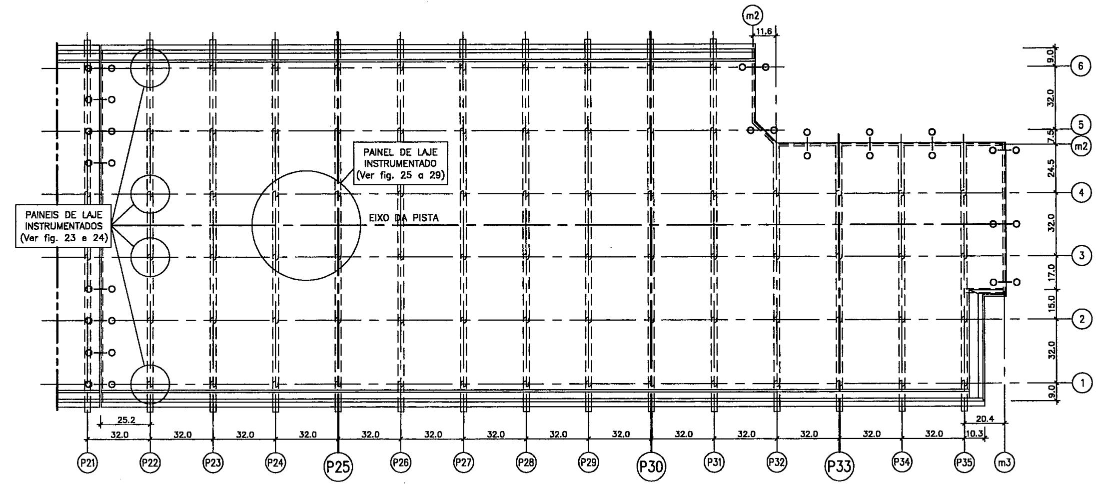


Figure 3. The instrumented plan of the 2nd phase extension

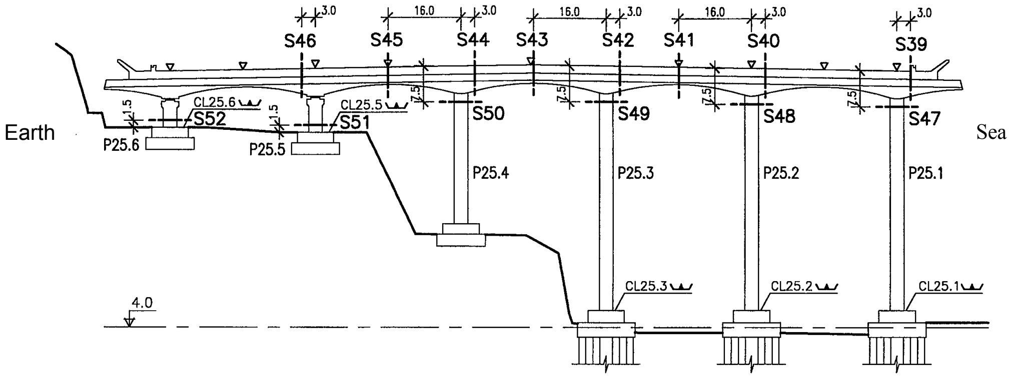
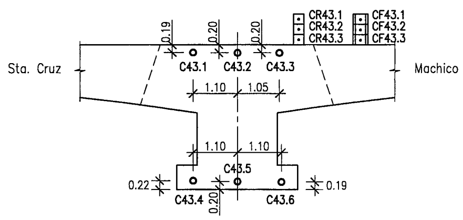


Figure 4. The instrumented portico - P25

Section S43 - strain meters



Section S43 - thermometers

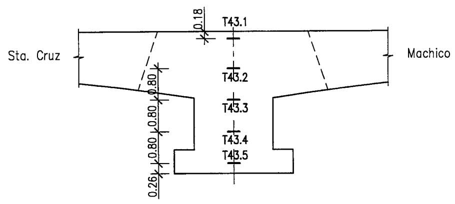


Figure 5. The instrumented section of the beam with strain meters

Figure 6. The instrumented section of the beam with thermometers

Section S50 - strain meters

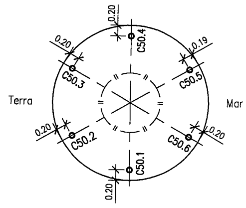


Figure 7. The instrumented section of the column with strain meters

Section S84L - strain meters

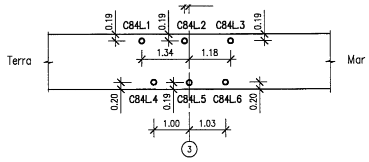


Figure 8. The instrumented section of the slab with strain meters

Figure 9. The creep and shrinkage compensator *in situ*

Figure 10. The truck loads

4. LOAD TESTS

Load tests were performed at both phase extensions in March of 2000, before the opening to the traffic, to check their behavior in association with the design numerical models. For the tests additional equipment was installed, namely associated with displacements and with dynamic characteristics.

4.1 Static tests

Static tests were performed with truck load up to a total of 5900 kN for the 1st phase extension and 7300 kN for the 2nd one (figure 10). These loads were placed in accordance to the load plan to obtain the most important effects in the structure. Figure 11 shows some load positions with maxim truck loads on 2nd phase extension.

The experimental results of the static load tests were interpreted by three dimensional finite element model. Generally the shell elements are used for the slab and the frame elements are used for the columns. The beam was divided on two parts: the top flange was included in the slab; the bottom flange and the web make the frame of beam (fig.12). The stiff frame united the two parts. The loads were modeled as joint forces. Figure 13 shows the computed deformed slab, carried up the load position 4E.

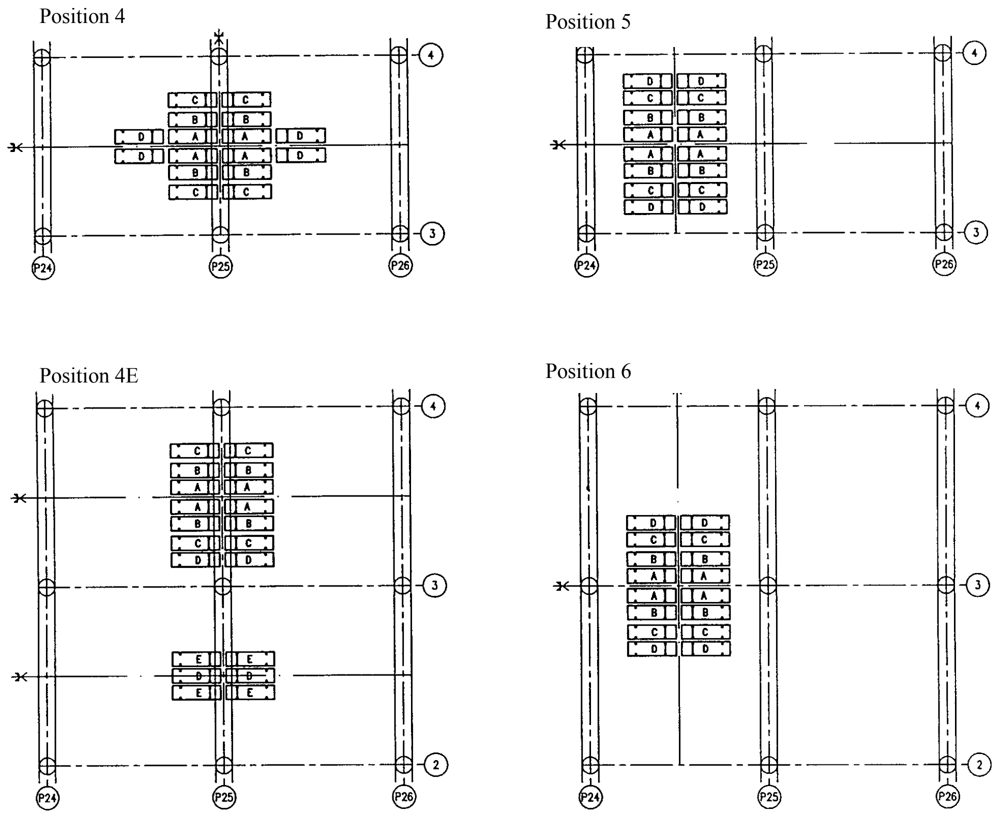


Figure 11. The distribution of truck loads (2nd phase)

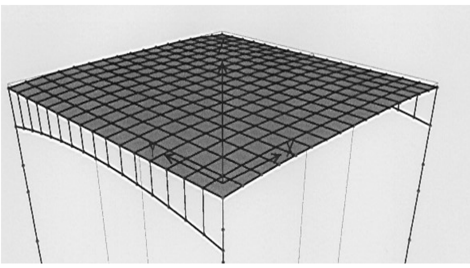


Figure 12. Analytical model

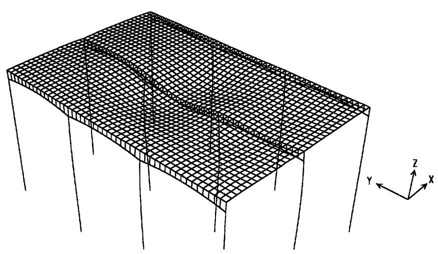


Figure 13. Deformed Shape (Pos. 4E)

Figure 14 shows the vertical displacement of the slab in the axis of the runway on those load positions. The maximum values of vertical displacement measured during these tests were 6.7 mm at the central midspan of P24-P25 when the loads were placed in position 5.

Figures15 and 16 shows the experimental and analytical strains in the beam section S43 and in the column section S50. Both sections are form frame P25 (figure 4). The strain meters locations were shown in figure 5 (S43) and figure 7 (S50).

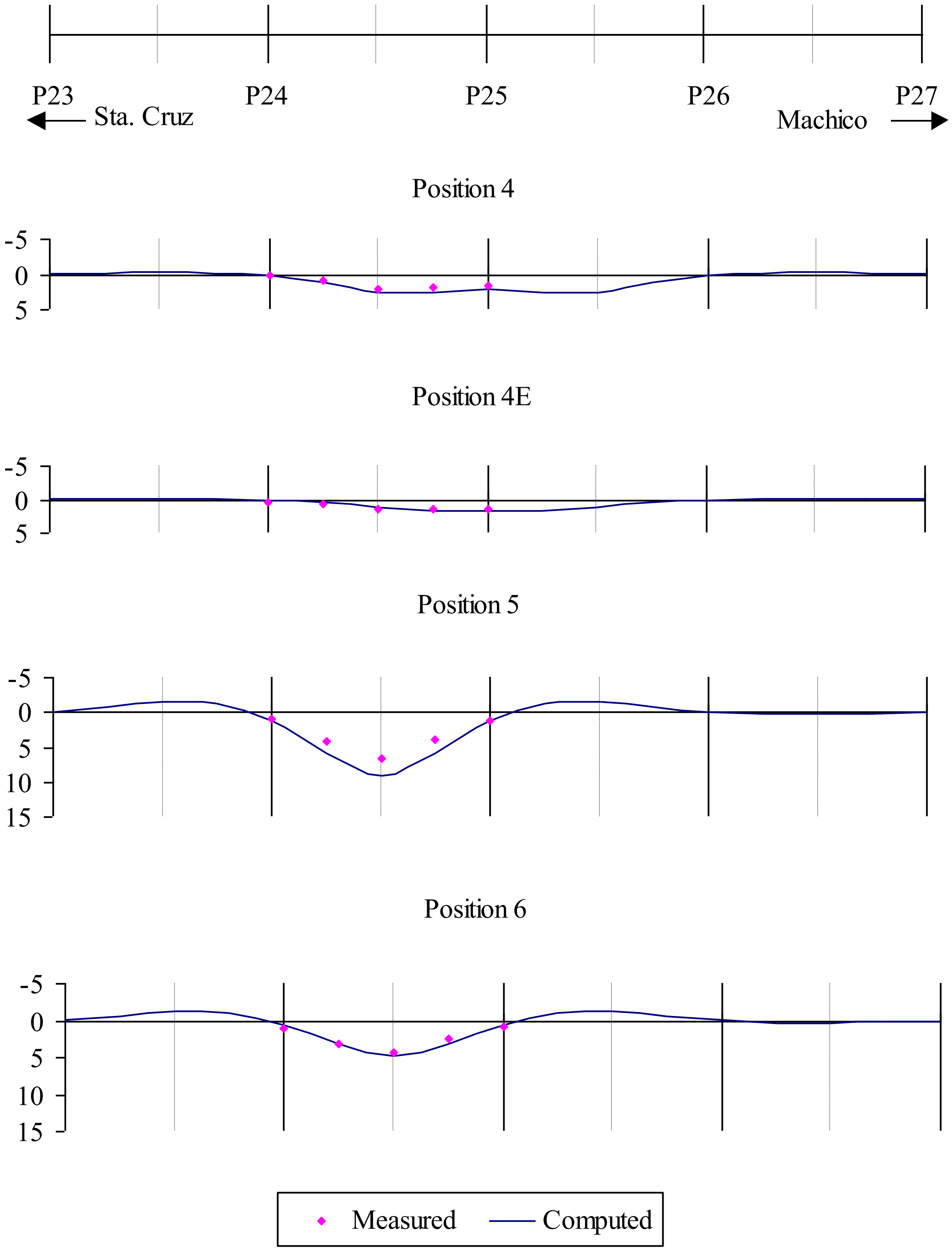


Figure 14. The vertical displacement of the 2nd phase slab in the axis of the runway (mm)

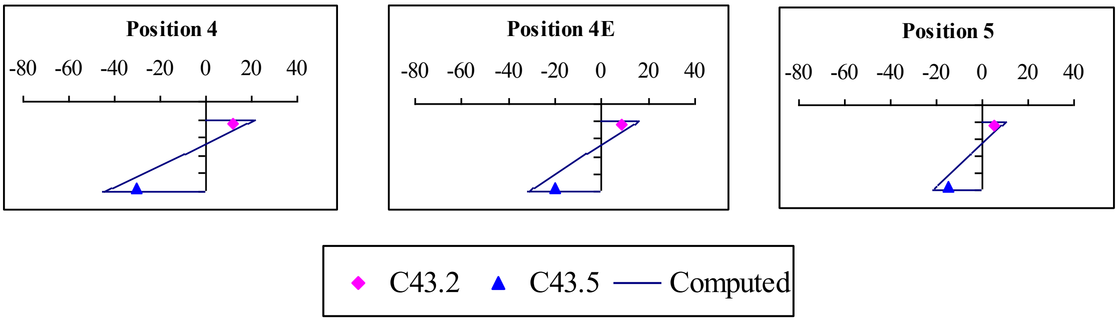


Figure 15. Experimental and computed strain in the beam section S43 (× 10^{-6}) (P25)

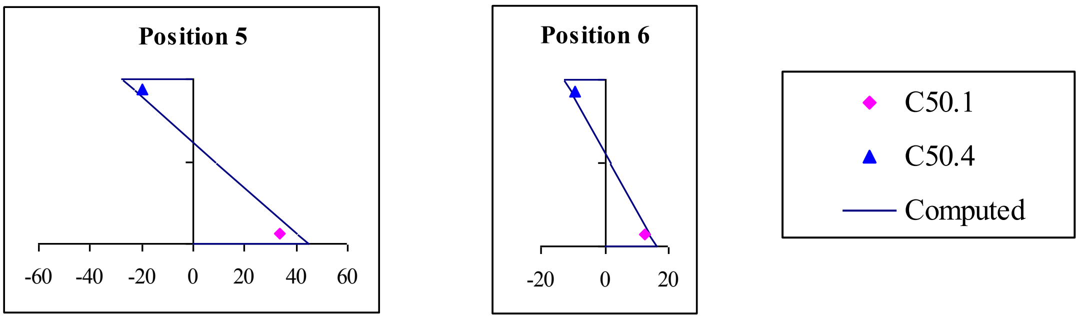


Figure 16. Experimental and computed strain in the column section S50 (× 10^{-6}) (P25)

4.2 Dynamic tests

Dynamic tests were performed in order to evaluate the dynamic characteristics of the structure, namely its frequencies, mode shapes and damping.

Two types of dynamic tests were performed. The first one consisted in the measurement of accelerations in the structures induced by the traffic of loaded trucks (the some ones used in the static tests) crossing over small wood planks.

The second type of tests consisted in the measurement of the structure response due to the sudden release of a 62 tons weight that was hanged from the mid-span of one slab (Figures 17).

Figures 18 and 19 show some results obtained in the 2nd type of dynamic tests.

Figure17. Dynamic test - suspended weight

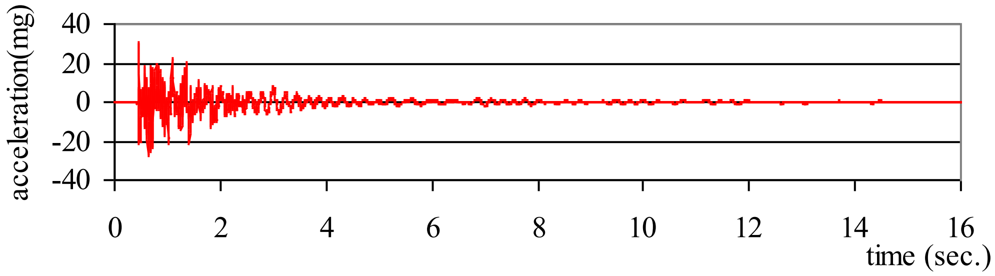


Figure 18. Measured acceleration

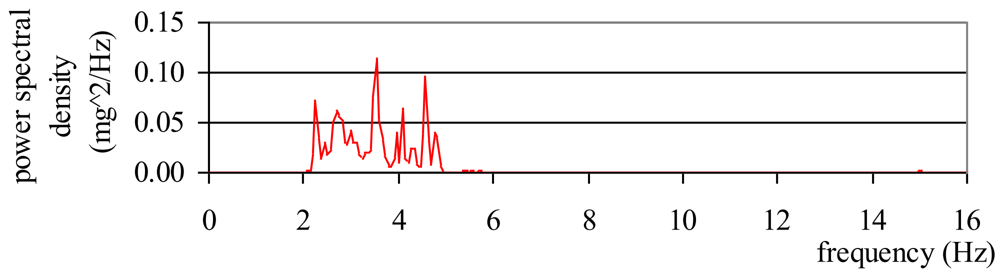


Figure 19. Measured spectra

5. CONCLUSIONS

The test results obtained in the 1st phase and 2nd phase extensions of Funchal Airport have a good correlation with analytical values. Generally, the numerical models adopted, at design stage, can correctly predict the real behavior of the structure.

6. ACKNOWLEDGEMENTS

The authors thank all who made this work possible, namely STA - Segadães Tavares & Assoc., ANAM – Aeroportos e Navegação Aérea da Madeira, S.A., Laboratório Nacional de Engenharia Civil and Fundação para Ciência e Tecnologia.

7. REFERENCES

SANTOS, T. Oliveira; FERNANDES, J. Almeida – *Observation of the structure of the Funchal airport extension – first phase*, NOE- LNEC, Lisbon, Feb.2000, 34p. (in portuguese).

SANTOS, T. Oliveira; FERNANDES, J. Almeida – *Observation of the structure of the Funchal airport extension – second phase*, NOE- LNEC, Lisbon, Sept.2000, 36p. (in portuguese).

SEGADÃES TAVARES, A.; VAZ, João – Funchal Airport. The Structural Solution - New Technologies in Structural Engineering, Lisbon, July 2-5, 1997, p.673(6p).