Construction of Prestressed Pavement at an Airport in Portugal

BY GOSWIN MITTELMANN

Describes the construction of a prestressed concrete runway and taxiway for an airport in Portugal. The pavement was pretensioned longitudinally and post-tensioned transversely. The runway is about 4000 m (13,100 ft) long and 60 m (197 ft) wide while the taxiway is approximately 3200 m (10,500 ft) long and 30 m (98 ft) wide. Each month about 270 tons (300 U.S. tons) of prestressing steel was installed and nearly 5500 cu m (7200 cu yd) of concrete was placed. The project was completed in 38 weeks.

Keywords: airports; concrete construction; concrete pavements; joints; post-tensioning; prestressed concrete; pretensioning; runways; slabs (nonmetallic); taxiways.

■ THE 16 CM (6 IN.) THICK prestressed pavement for this airport[1] consists of a 400 x 60 m (13,100 x 197 ft) runway and a 3200 x 30 m (10,500 x 98 ft) taxiway. See Fig. 1 for a typical cross section of the pavement. Altogether, about 53,800 cu m (70,400 cu yd) of concrete was used. The flexural strength of the concrete at 28 days was specified as 55 kg per sq cm (786 psi).

Following the common working width of finishers, the runway and taxiway were cast in 7.5 m (24.6 ft) wide strips. The runway slabs were divided into six 667 m (2180 ft) prestressing strips. The taxiway was divided into three strips 680 m (745 yd) long and two fields 580 m (634 yd) long. Each field was divided into sections 97.14 m (106 yd) long. Each runway field, in turn, was divided into seven 95.24 m (104 yd) sections.

The above breakdown resulted in 68 prestressing strips comprising about 5000 sq m (6000 sq yd) of concrete. The entire prestressing strip had to be placed in one operation.

The paving equipment consisted of one spreader, two finishers, and one curing film sprayer. A total distance of 45 km (28 miles) had to be paved. A paper-laying machine (see Fig. 2) covered this same distance on track forms. This machine placed the entire paper between slab and subbase for one strip in one operation (see Fig. 3).

The prestressing strips are bordered at each end by concrete abutments which have to transmit to the foundation the horizontal anchorage force for 15 tendons over a width of 7.5 m (24.6 ft). The tendons are spaced at 50 cm (1 ft 8 in.) and each tendon consists of six wires. An initial prestress of 8800 kg per sq cm (126,000 psi) was used. Thus, the abutments have to resist a lateral force of 47.5 tons per m (15.9 U.S. tons per ft) with a safety factor of 1.2. The cross section of the abutment is 6.28 sq m (67.5 sq ft) and the total length of the abutment is 420 m (1380 ft) for the runway and 180 m (591 ft) for the taxiway. The abutment is assumed to act with a width of 18.75 m (61.5 ft) in resisting the anchorage forces of a 7.5 m (24.6 ft) wide prestressing strip.

At the abutments and between the 95.24 m (104 yd) long sections, steel joints are provided to allow movements due to temperature, creep, and shrinkage changes. A total of 480 7.5 m (24.6 ft) long double joints were required (see Fig. 4). Along the border between the prestressed concrete and unprestressed concrete areas (longitudinal joints), light steel angles were used to allow the large differential movements, since joint sealing compounds could not withstand the relatively large movements.

LONGITUDINAL PRESTRESSING

To produce an initial longitudinal stress of 24 kg per sq cm (341 psi), about 3.84 kg per sq m (0.8 lb per sq ft) of prestressing steel was required. The magnitude of the initial stress is determined from the temperature gradient, E =

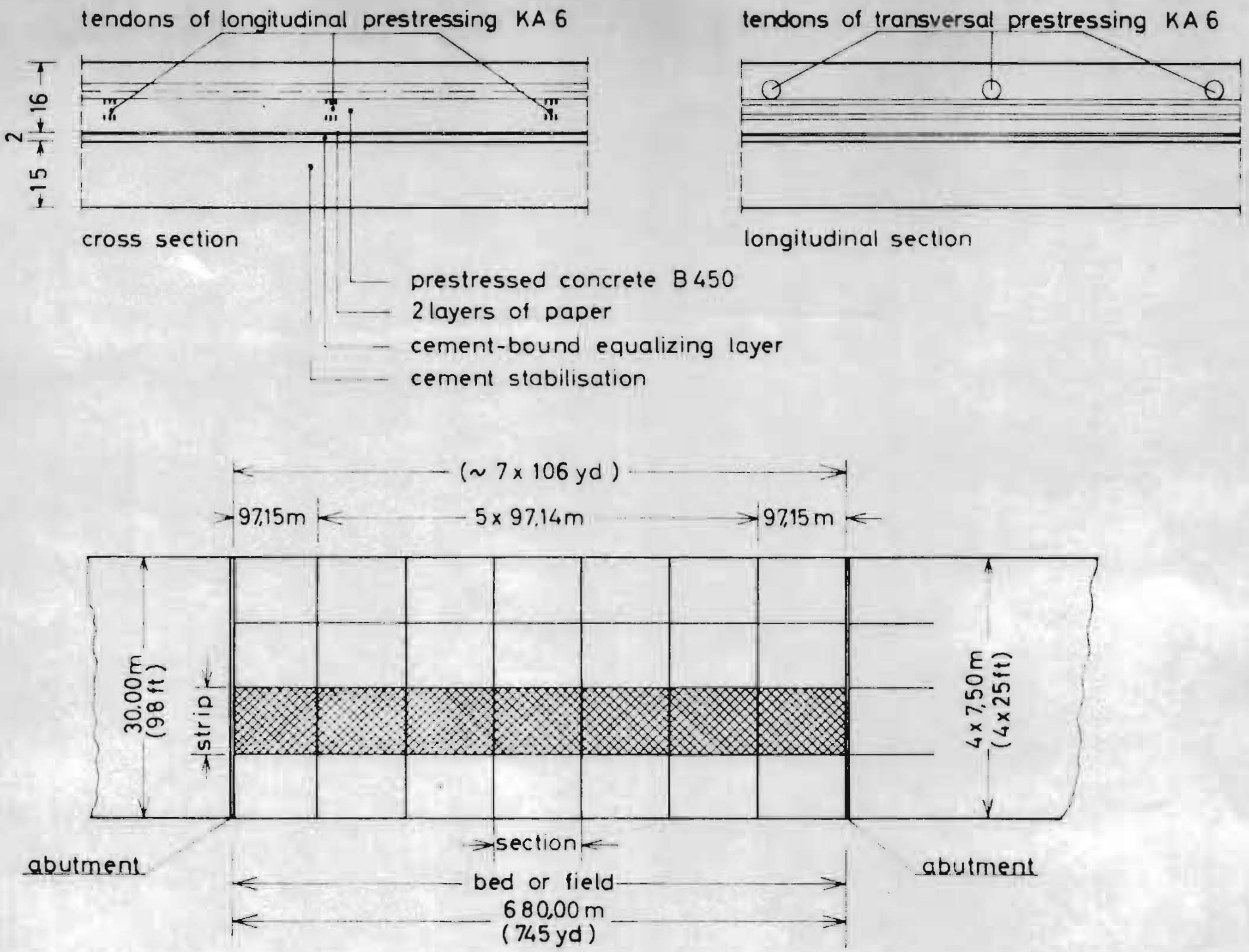

Fig. 1—Longitudinal and transverse sections of prestressed concrete slab and notation used for prestressed concrete system

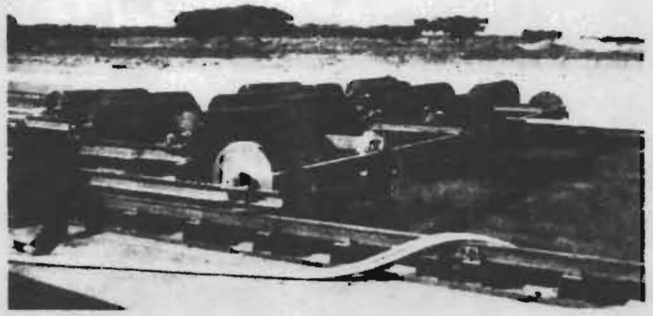

Fig. 2—Paper-laying machine; running once over the prestressing strip 5000 sq m, this machine places the total quantity of paper for separating the slab and subbase; there are two layers of paper of 180 g per sq m (5.4 oz per sq yd)

Fig. 3—Placing of paper; to protect the paper against wind, it is loaded with wood lathes

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350,000 kg per sq cm (5,000,000 psi), from the given live load moment of 1.62 m tons per m (3570 ft-lb per ft), and flexural safety factor of 1.25.

The wire-laying machine placed six 680 m (745 yd) wires simultaneously between abutments (see Fig. 5 and 6). The tendons were pretensioned from one end of the prestressing strip.

TRANSVERSE POST-TENSIONING

For post-tensioning in the transverse direction about 643,000 m (700,000 yd) of sheathing had to be installed. The 7.5 m (24.6 ft) long sheaths were fabricated on the site. At the ends of the sheaths along the joints between the 7.5 m wide strips, screwed pipe joints were used for splicing. The above layout resulted in about 28,000 tensioning points (see Fig. 7). After post-tensioning, the transverse tendons were grouted in their sheaths. This required 518,000 l (18,300 cu ft) of cement grout.

CONCRETING OPERATIONS

The concreting plant comprised two 1000 l (264 gal) turbo-pan mixers. Each mixer had a radial scraper plant, two 500 ton capacity cement hoppers, and radially arranged boxes which were supplied by conveyor belts. The bins could store aggregates for about 350 cu m (458 cu yd) of concrete. The maximum output of the plant was approximately 60 cu m (78.5 cu yd) of compacted concrete per hour. Within 15 to 20 hr the plant placed about 800 cu m (1040 cu yd) of concrete continuously. The concrete was transported to the site in eight trucks. These trucks were equipped with steel troughs to insure proper dumping into the spreader (see Fig. 8).

The placing equipment consisted of a closed hopper-type concrete spreader and two finishers with jointed finishing units.

CONSTRUCTION PROCEDURES

When the soil cement foundation was stabilized a typical 5000 sq m (6000 sq yd) prestressing strip was constructed as follows:

First, the track forms were installed. Before the paper was laid, a smooth 2 cm ($\frac{3}{4}$ in.) special concrete layer was cast using a shovel-type

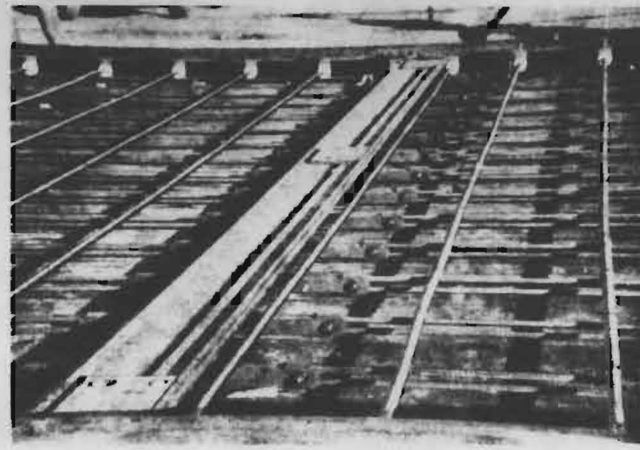

Fig. 4—Installation of steel joints; these steel joints are installed after placing the wires; while tensioning the tendons in the prestressing field they serve as protection against an upward movement of the wires (which eventually break); later, the lashes of the steel joints are clamped to the tensioned wires so that after concreting of the prestressing strip (when the wires in the joint are cut through), the prestressing force of the tendons can be transmitted to the front surface of each section

Fig. 5—Installation of prestressing steel; the wire-laying machine places about 20 tons (22 U.S. tons) of prestressing steel in the longitudinal direction when running between two abutments of a prestressing strip

Fig. 6—Prestressing arrangement prior to concreting (note protective tents at left)

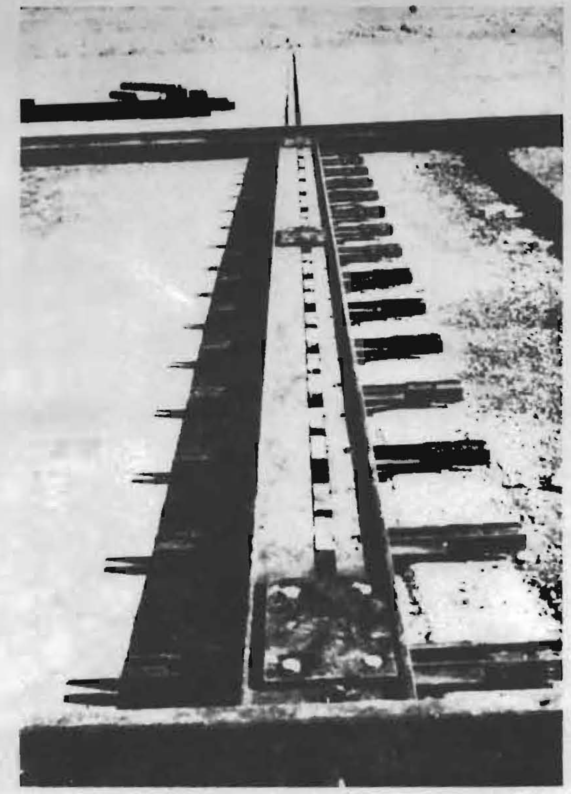

Fig. 7—Built-in tensioning joint; this type of joint is placed between two prestressing fields; it is installed on the abutment; the steel plates situated vertically between the angles transmit the anchorage force of the tensioned wires in the prestressing field (not yet installed in the photograph) from the joints to the abutment

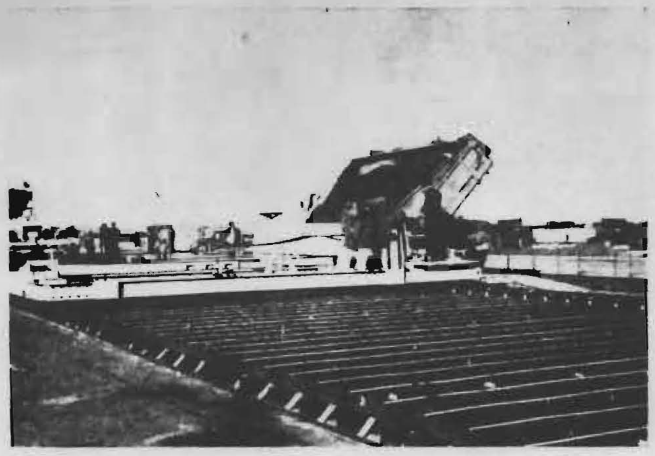

Fig. 8—Concreting of a prestressing strip

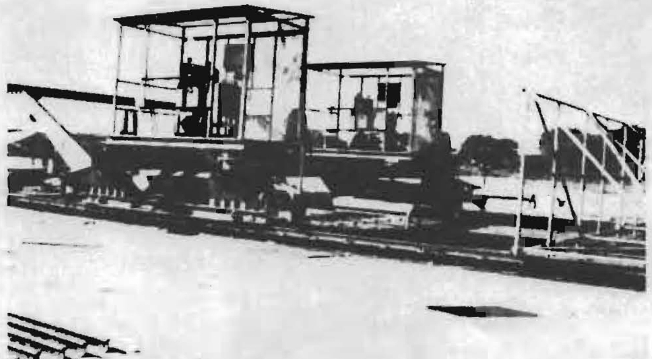

Fig. 9—Longitudinal prestressing jacks with safety device at right; before installation of the sheaths (i.e., before concreting a prestressing strip) the 15 tendons of the longitudinal prestressing are tensioned by these tensioning devices in less than 1 hr; the tendons are stretched by more than 3 m (about 10 ft)

spreader and finisher. About 20 tons (22 U.S. tons) of prestressing steel was placed longitudinally (see Fig. 5). Each of the 15 tendons had six wires. Prior to tensioning the tendons, six steel construction joints for the transverse joints between the sections and two safety beams per section were placed by a moving crane. A safety device was mounted at each end (see Fig. 9). The tensioning was done by a newly-developed hydraulic machine which stretched the tendons about 3 m (10 ft) in one operation. The tensioned wires were separated by spacers and clamped to the lashings of the intermediate joints. Sheaths (about 1330 units), each stiffened with three 12 mm (0.5 in.) diameter bars and one 8 mm (0.3 in.) diameter bar, were placed on the longitudinal tendons. Then the concrete was placed. Working tents, 150 m (500 ft) long, were installed to protect the fresh concrete. The tents also avoided interruptions due to bad weather. To prevent drying shrinkage cracks a curing film was applied. Curing was also aided by covering the fresh concrete with straw mats. When the concrete reached its specified strength it was stressed longitudinally by separating the tendons from the abutments and by cutting the wires between the two parts

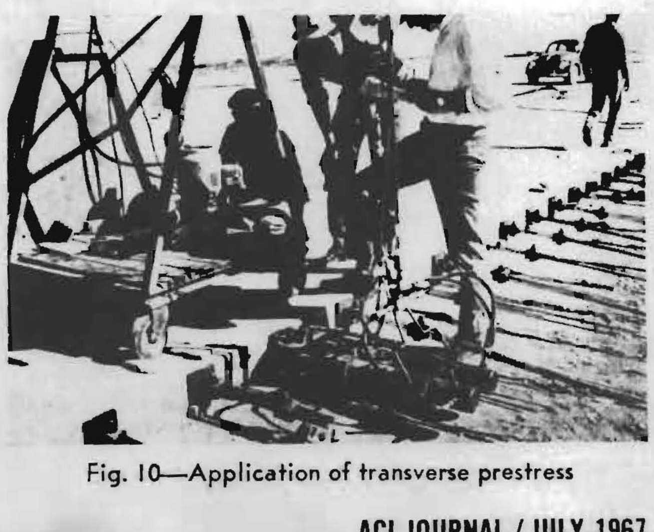

Fig. 10—Application of transverse prestress

of each steel joint. After this, the covering was removed from the pavement. The threading and tensioning of the 1300 transverse tendons could be done only after the full width of the runway was completed. Fig. 10 shows the application of transverse prestress. Altogether there were 2600 tensioning points per prestressing field. Four units of a special tensioning device, which could stretch the tendons accurately in a single operation, were used.

The tendon forces were controlled by a dynamometer. The field readings showed that friction forces agreed with those assumed in the stress calculations.

It is expected that the entire area of 336,000 sq m (400,000 sq yd) constructed with the prestressing field system[2] will be completed on schedule and will be without cracks.

The construction of this runway and taxiway was undertaken in 1965. Although the first application of prestressing to highway pavements was begun in 1958, the literature on this subject is scant. It is hoped that the following references[1-7] will serve as a start in this important field.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Martin Schulz and Christine Reifart for their valuable help in the English translation of this manuscript.

The contract for the construction of this airport was undertaken by the Overseas Department of Philipp Holzmann A. G., Frankfurt, West Germany. The contract included the delivery of steel and special materials as well as the planning, supervision of construction, and supply of specialized personnel.

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This paper was received by the Institute Aug. 4, 1966.

Sinopsis—Résumé—Zusammenfassung

Construcción de Pavimento Presforzado en el Aeropuerto en Portugal

Se describe la construcción de una pista y antepista de concreto presforzado para el aeropuerto en Portugal. El pavimento fue pretensado longitudinalmente y postensado transversalmente. La pista tiene cerca de 4000 metros (13100) pies) de largo y 60 metros (197 pies) de ancho mientras la antepista tiene aproximadamente 3200 metros (10500 pies) de largo y 30 m (98 pies) de ancho. Se instalaron aproximadamente 270 toneladas de acero de presfuerzo y casi 5500 m³ (7200 yd.³) de concreto por mes. El proyecto fue completado en 38 semanas.

Construction d'une piste précontrainte à l'aéroport en Portugal

Cet article décrit la construction de pistes d'atterrissage et de dégagement pour l'aéroport en Portugal. La dalle a été précontrainte par fils adhérents dans la direction longitudinale et post-contrainte dans la direction transversale. La piste d'atterrissage fait environ 4000 m de longueur et 60 m de largeur. Quant à la piste de dégagement, elle fait environ 3200 m de longueur et 30 m de largeur. Chaque mois, environ 270 tonnes d'acier de précontrainte et près de 5500 mètres cubes de béton étaient mis en place. La construction a été réalisée en 38 semaines.

Herstellung von Spannbetondecken für einen Flugplatz in Portugal

Berichte über die Herstellung von Spannbetondecken für die Startbahn und die Rollbahn eines Flugplatzes in Portugal. In Längsrichtung wurde ein Verfahren mit sofortigem Verbund angewendet, in Querrichtung ein solches mit nachträglichem Verbund. Die Startbahn ist 4000 m lang und 60 m breit, während die Rollbahn ungefähr 3200 m lang und 30 m breit ist. Jeden Monat wurden etwa 270 t Spannstahl und 5500 m³ Beton eingebaut. Das Projekt wurde innerhalb von 38 Wochen im Jahre 1965 ausgeführt.

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Hanrahan Honored

Frank J. Hanrahan, executive vice-president, American Institute of Timber Construction, has been named recipient of the American Society for Testing and Materials' *Walter C. Voss Award* for 1967.

Mr. Hanrahan received the award "for his lifelong efforts in the promotion of research and education on the structural use of wood, his active participation in the formulations of standards and codes for wood and wood-base materials, and especially for his leadership in the advancement of glued-laminated timber to its present status as an engineered construction material."

In addition to ASTM, Mr. Hanrahan is a member of ACI, and a Fellow of the American Society of Mechanical Engineers. He is also active in many other professional societies.

General Portland Cement locates in Dallas

The corporate offices of the General Portland Cement Co., formerly in Chicago, are now located in Dallas, Tex.

Proceedings of USU concrete conference now available

Proceedings of the Ninth Annual Concrete Conference held at Utah State University, March 2-3, are now available. The conference featured papers on a variety of subjects from "Diagnosing Concrete Failure" to "Concrete in the Future." Further information is available from J. Derle Thorpe, executive secretary, Concrete Conference Committee, Utah State University, Logan, Utah.

Errata

The following corrections should be made in "Construction of Prestressed Pavement at an Airport in Portugal" which appeared in the July 1967 JOURNAL.

p. 393—Line 2 change "400" to "4000."

p. 397—Line 17 of the left hand column change the reference citation to "3."

p. 397—change the sentence beginning on Line 20 of the left hand column to read "Although the first application of the field system of prestressing to runway and highway pavements was begun in 1958, the literature on this subject is scant."