THE APPLICATION OF PRESTRESSED CONCRETE TO THE CONSTRUCTION OF AIRFIELD PAVEMENT

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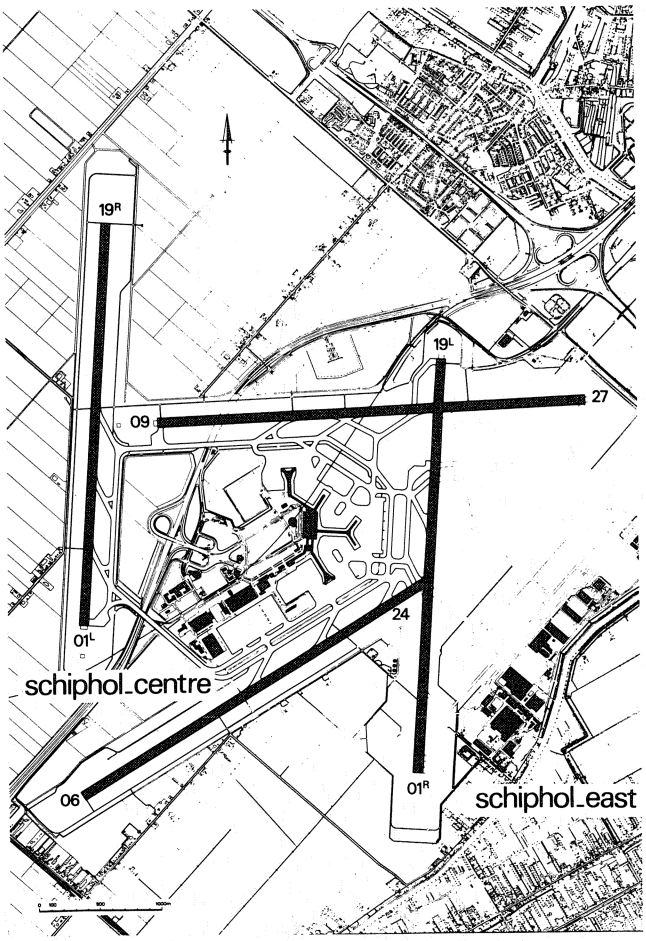
Abstract

In this paper the following subjects are presented:
1. The History of the Airport. 2. The choice of prestressed concrete for airport pavement. 3. Soil conditions and foundation. 4. Prestressed concrete constructions. 5. Further possibility of constructing the expansion joint between two slabs. 6. Further developments. 7. Design criteria. 8. Tests. 9. Experience and maintenance. 10. Construction and maintenance costs.

1. History

Schiphol airport, located in the immediate vicinity of Amsterdam, is the National Airport of the Netherlands. This airport ranks sixth in Europe with respect to the passenger traffic (10 million in 1979)and was rated fourth in Europe for its cargo handling of approximately 300.000 tons in 1979.
Considering the total surface area of approximately 1800 hectare, Schiphol is one of the biggest airports in the world. This is mainly due to the layout of the airport, which provides four take off - landing runways which are located tangentially to a central area. Until 1967, the needs of the Netherlands were sufficed by so called "Old Schiphol" airport, situaded to the east and forming part of the presentday Schiphol. Since last few years the "Old Schiphol" has been used intensively as a technical service area on which two wide body hangars have been built and presently a third hangar is under construction for the maintenance of the Airbus A300. Schiphol airport serves as a base for the Durch National Airline K.L.M. and about 65 other airlines make use of its facilities for their nomal as well charter flights to transport cargo or passengers.
In order to obtain a good Dutch perspective, the airport has been constructed on the bottom of a former 18000 hectare lake which was pumped dry in 1855 to procure land. In the North-east corner of this former lake the first development of an airport began in 1920 and just last year we celebrated the 60th anniversary of the airport.
"Schiphol" owes its good position in European rankings not only to its excellent cargo and passenger

Figure 1. Lay-out of Schiphol-airport



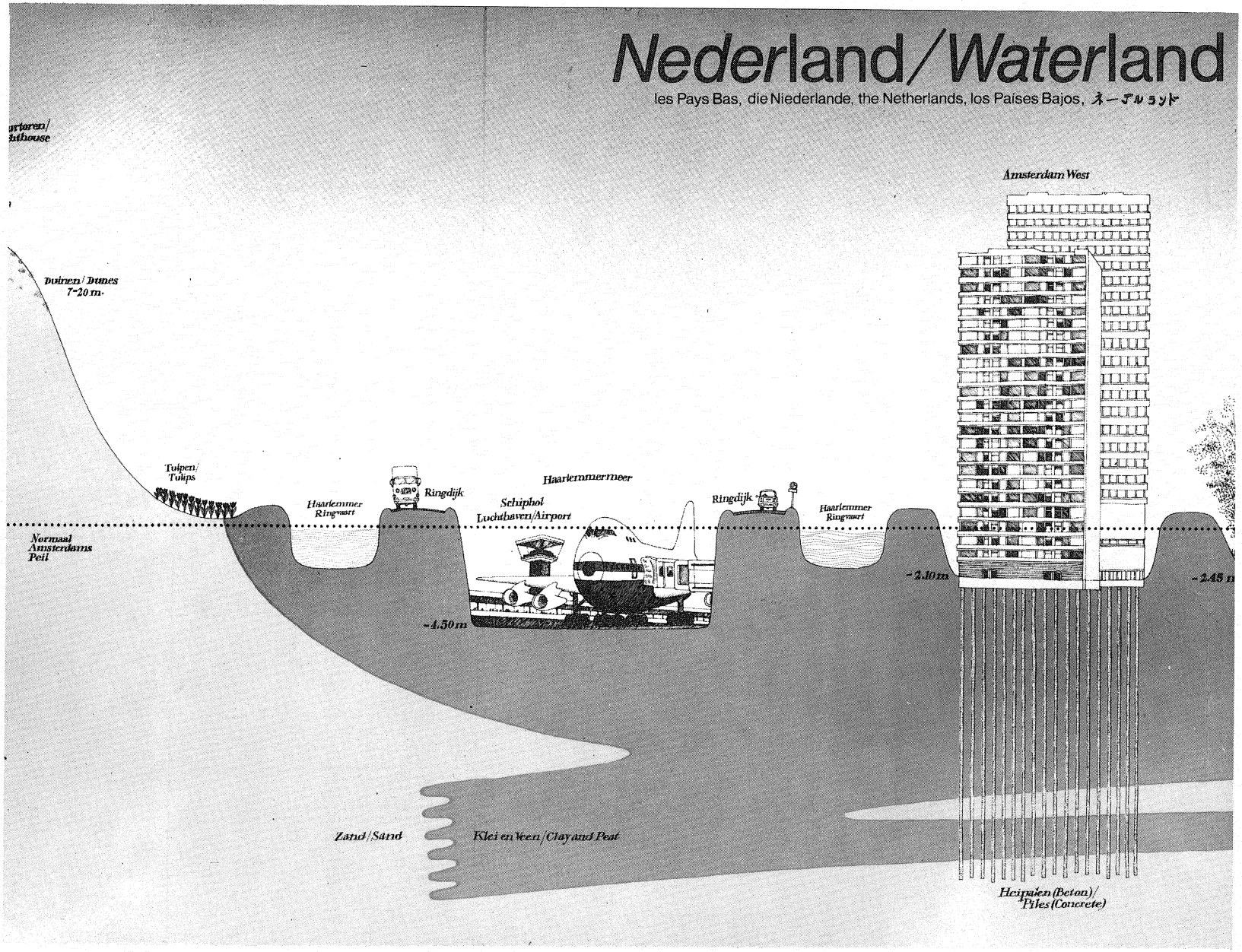


Figure 2: Cross-section sketch showing the level of Schiphol-Airport.

handling faulities also to its good technical services and well planned airport pavement.

2. The choice of prestressed concrete for airport pavement.

As stated previously, the existing airport was opened in 1967 and in the years 1960 to 1965 a study was made for the type of pavement which should be used for this airport.
For the construction of the upper layers of a pavement, two types of materials were mainly available; namely, asphalt and concrete.
The properties of asphalt show that under continuous heavy load or a heavy load combined with temperature development, a plastic deformation occurs, also, asphalt can be damaged by an action of the aeroplane fuel-kerosine. These aspects have led to the choice of concrete to construct pavements for aprons, ends of runways and floors for hangars. The remaining pavements have been constructed in asphalt.
This choice of concrete gives opportunity to use various types of constructions, like:
a. concrete slabs without reinforcement
b. reinforced slabs
c. continuous Reinforced concrete slabs
d. prestressed concrete slabs.

The use of prestressed concrete as the top layer of pavement reduces the maintenance considerably (less joints, no cracks) and this aspect, at the same time, has led to the choice of the prestressed concrete.
In 1966, the start was made by introducing prestressed concrete to the construction of present Schiphol airport. Since then an average of 40.000 sg. mts. of prestressed concrete per year has been used for repairing the old pavements and for the new extensions. This has resulted in approximately 700.000 sg.mts. of prestressed concrete pavement which is being used at present of which the first part is nearly 15 years old.
Also, prestressed concrete aprons are under construction at present and further extensions to aprons, floors of hangars and runways are being planned.
This total area of prestressed concrete already constructed and the intention to use the same construction for future extensions proves the excellent choice made previously.

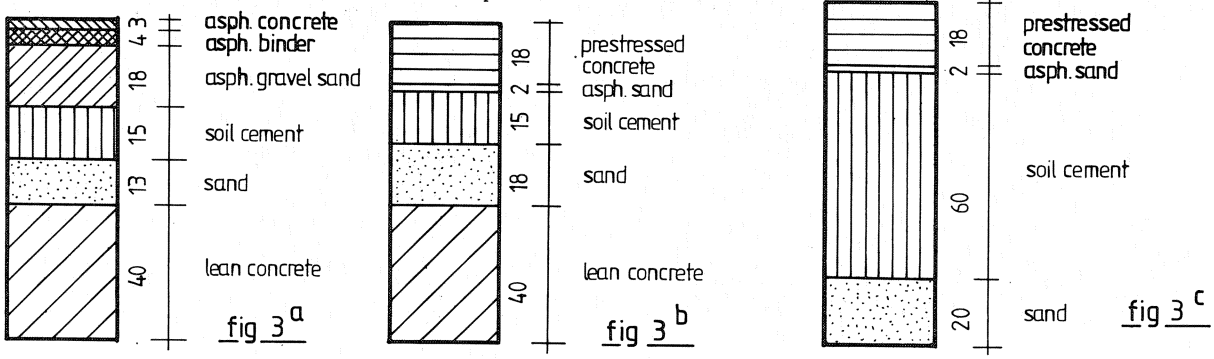
3. Soil conditions and foundation:

Although this subject is outside the scope of this paper, and depends on local circumstances, the following has been observed.

Photo-1: Aerial view Schiphol Centre: Parking bays along the piers have been constructed with prestressed concrete.



Figure-3a: sandwich construction with asphalt surfacing
Figure-3b: sandwich construction with prestressed concrete slab
Figure-3c: sand-cement stabilization with prestressed concrete slab



The airport is built on the bottom of a former lake and is approximately 4 metres below the sea level. The soil conditions consist of an upper layer of one metre thick clay under which there is a 8 metres thick layer of clayey sand with high water contents. An extensive Dutch study in 1950 for a good pavement foundation resulted in developing the well-known sandwich-construction. On this foundation asphalt surfacing is done or the prestressed concrete slabs are constructed. Due to economic considerations in 1972, only in case of prestressed concrete surfacing, foundation was changed to 60 cm. thick layer of sand cement stabilization. The testresults show that there is practically no qualitative difference between a sandwich construction and a 60 cm thick sand-cement stabilization.

4. Prestressed concrete constructions used in the past.

During the period that prestressed concrete has been used, the Technical Maintenance Section of Schiphol airport has introduced various modifacitions to improve the prestressed concrete pavement construction, economically as well as technically. Following the extensive research, we are now at the point to introduce considerable number of changes in the construction of prestressed concrete pavements for the prestressing as well as for the demensions of the slabs and joint-constructions. The methods used so far and the new developments are discussed further, under A and B respectively.

Figure-4: Plan of prestressed concrete pavement around a pier.

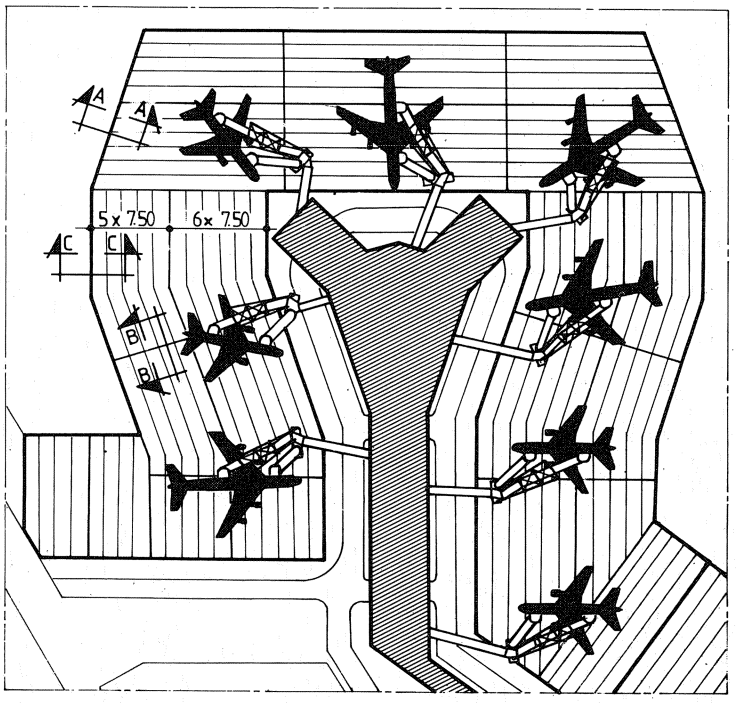
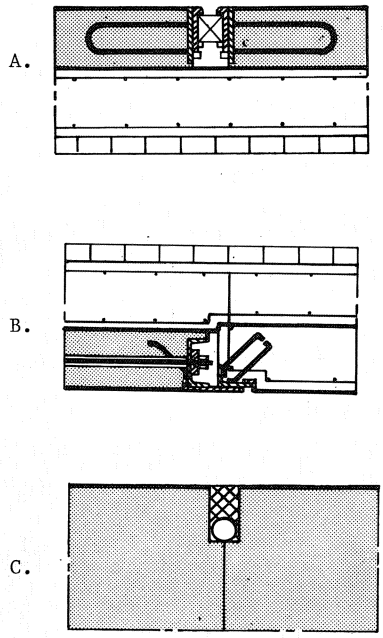


Figure-5: A: Neoprene Joint
B: Schleppblech Joint
C: Expoxy Joint



A. Methods used so far:

I. General

For the application of prestressed concrete, considering the example of apron pavement, slabs having 0,18 m. thickness and 7,50 m. width are constructed.
The slabs length is varied from about 30 m. to a maximum of 120 m. The greater lengths, if required, can be achieved by introducing an expansion joint between the standard lengths. These slabs are stressed longitudinaly in various stages directly after the casting.
Depending on the designwidth of the pavement, slabs are cast next to each other to a maximum width of 9 slabs (67,50 m) and are stressed transversely after complete hardening of concrete. In case, a greater width is required (say 90 m), then two sections each having width of 6 slabs and separated by a beam or a drainage gutter can be constructed. The slabs are constructed with a slope of 1% to facilitate easy drainage. The edges of the prestressed concrete pavement, longitudinal as well as transverse, are always provided with a concrete beam or a drainage gutter. Not only the straight areas, but the curved forms can also be constructed by using prestressed concrete without any problem. (see figure-4)
Necessary openings in the concrete slab (required to construct foundations for Aviobridges and lighting towers etc.) can be constructed without any problems. This can also be done while the pavement is being used. In this case specific areas of the prestressed slab can be removed by applying special technics.

II. Joints: (see figures 5a, 5b, 5c).

It is a normal phenomenon that the concrete slab has its weakest cross-section at the edges, and therefore, at the joints a reinforced concrete slab is provided under the prestressed concrete slab. Due to its expanding and shrinking properties, the concrete surface is enclosed all around by joint construction.
For the transverse joints (maximum at 120 m) a type of joint that can expand ± 6 cm. and can withstand aeroplane loadings is used. Until now, mostly "Acme" joints, comprising Neoprane section cast in steel profiles, were used for this purpose. The high prices of this joint construction has led to the use of "Schleppblech" joint. This joint consists of a steel plate fixed to the concrete slab at one end and the other end slides over a steel section cast into an adjacent concrete slab or a concrete beam or a drainage gutter. After the hardening of a complete concrete slab section, the Neoprane or the Schleppblech joints are constructed. The hollow space under the Neoprane or the Schleppblech joint requires a provision of good drainage facility so as to avoid the frost damages in consequence of the accumulation of rain and melting snow water.

The longitudinal joint between the prestressed concrete pavement area and the edge beam or drainage gutter have a small expansion and therefore the joint can be constructed by injecting neoprane into a specially formed space after complete hardening of the concrete.
After stressing the concrete slabs in transverse direction, the longitudinal joint between the two adjacently cast slabs is cut with saw and filled with synthetic joint filler.

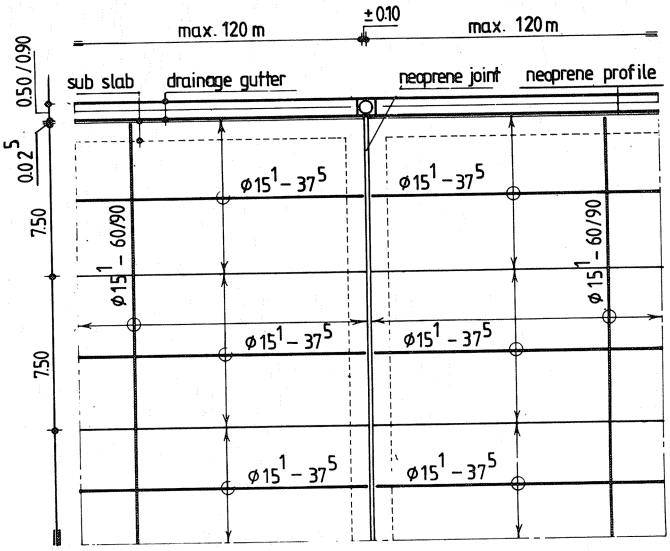


Figure-6: Partial of prestressed slabs.

III. Prestressing systems: (see figures 6 and 7).

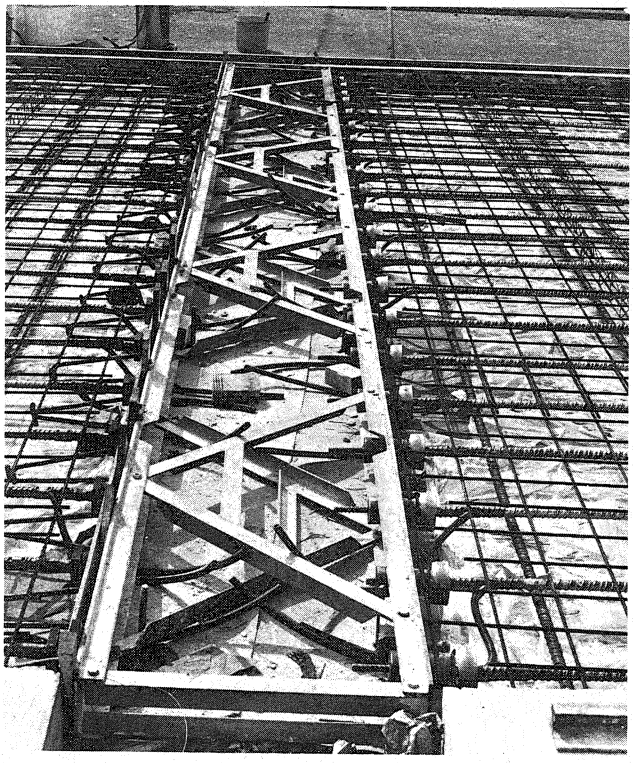
For prestressing, Diwidag-system developed by Dyckerhoff and Widdmann of Munick, West Germany has been used. This system comprises of high tensile steel bars in ducts placed in longitudinal as well as transverse direction to form the net. The ducts are injected after the tensioning of Dywidag steel bars.
The steel for the longitudinal and transverse reinforcement comprises of ribbed prestressing steel bars Ø 15,1 mm, sigma steel. The longitudinal bars at 0.375 m, centre to centre and the transverse bars at 0.60/0.90 m. The longitudinal steel bars be over the transverse bars having concrete cover of 3m5 cm. At the tension ends the bars are brought to the centre of the slab height.

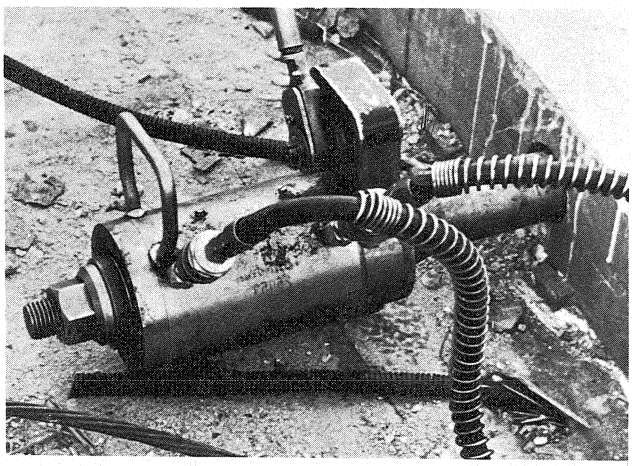
IV. Longitudinal reinforcement: (see fig. 7A & B)

The bars are about 25 m. long and are connected, if required, by using a threaded sleeve. During the placing of the bars the ducts are brought in around the bars. These ducts having diameter of 23 mm and the wall thickness of 0,2 mm are spirally rolled and are known as "Drossbach" ducts.

At the threaded sleeves these ducts are widened over a length of 0,50 m, so that the sleeves have the required room for movement during the tensioning. The shuttering of the joint construction forms the anchor against which the bars are tensioned. At these anchor positions, required holes are drilled in the steel profile and small tubes are welded to the rearside of the profile with the provision of anchor plates.
The connection between the ducts and the anchor plates is made by the use of a synthetic pipe having a connection for the injection of grout.
Due to the consideration for the spreading of stresses, a steel mesh is provided over a width of 1,5 m directly behind the formwork of the joint.
In order to prevent the cracks partial stressing of the slab is done as soon as possible. Experience has shown that the following stressing sequence must be used:
stress upto 25 % at a compressive
strength of 9,3 N per mm2
stress upto 50 % at a compressive

photo-2: Joint between slabs A and B





strength of 13,9 N per mm^2
stress up to 80% at a compressive
strength of 23,2 N per mm^2
stress up to 100% at a compressive
strength of 40,6 N per mm^2

By testing the cubes, cast at the same time as the slabs, the compressive strength development in concrete can be determined at various hardening stages and the amount of stressing at various stages can be decided.
The stressing is done by using 20 kN jacks which are normally used on both ends.
The anchoring of the bars is achieved by turning a nut which fits exactly on the threaded end of the bars.
The transverse joint having embeded profiles between the two slabs has a width of about 10 cm at the final stage of construction. It must be clear that for the stressing in this way requires a special care. (see figure 7B and photo-3).

Supposing that we have two slabs A and B which require stressing. Slab A is cast completely and is provided with the normal joint profile. While casting of the slab B, a space of 70 cm. is provided between the slabs A and B. This is required for the stressing equipment. In order to tension slab B at this stage, the bars are provided with a conventional anchor.
Both slabs now can be fully stressed. The stressed bars of slab B are lengthened by using a coupling sleeve having bars with $\pm$ 70 cm. length. At this point the profile of slab B is placed over the bar ends. The bar ends are covered with ducts and space between the slabs A and B is cast with concrete. After the hardening of this concrete the joint is reduced to 10 cm. This special flat jack tensions the already stressed bars in such a way that the anchor nut, previously places, is set free from its seat.

V. Transverse stressing: (see figure-7C)

For the transverse reinforcement, initially the standard length (7,5m) ducts are placed in position and fixed to the side of the wooden formwork at required centre to centre distance. Hereafter a part of the 25 m. long prestressing bars are pushed in the ducts. At this point, with regards to transverse steel, the slab is ready for casting. Before casing the adjacent slab, the ducts are placed and the transverse prestressing bars are pushed once again through over a width of 7,5 m. (width of a slab). This operation is repeated for the number of bays between two expansion joints. In the order of casting of slabs, so called "coupling plates" are used to couple the prestressing bars similar to the coupling of longitudinal bars. Conventional anchors, fixed on the formwork at the edges, are used. Transverse stressing is done after complete hardening of all the bays.

VI. Injection:

After complete stressing of bars in the slab area the ducts are grouted. For this grouting an electric pump is used and the pumping of grout is continued till the grout runs out through the duct end on the other side.
Intermediate check holes for the grouting are superfluons and are not used anymore.
As mentioned before, the sides of a slab area must be surrounded by a concrete beam or a drainage gutter.
It is obvious that the beam or a gutter should be case in two stages, the last after the stressing of the transverse bars (see figure-7C).

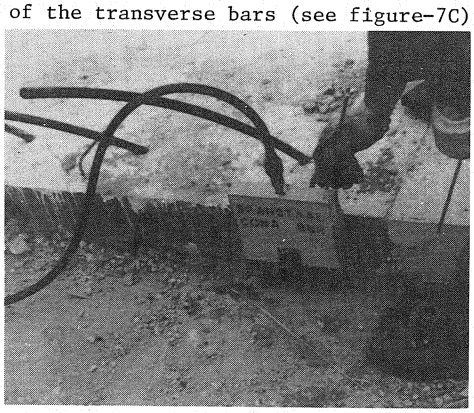


photo-4:

Use of special flot jack

FIG. 7[a] CROSS-SECTION A-A (see also figure 4)

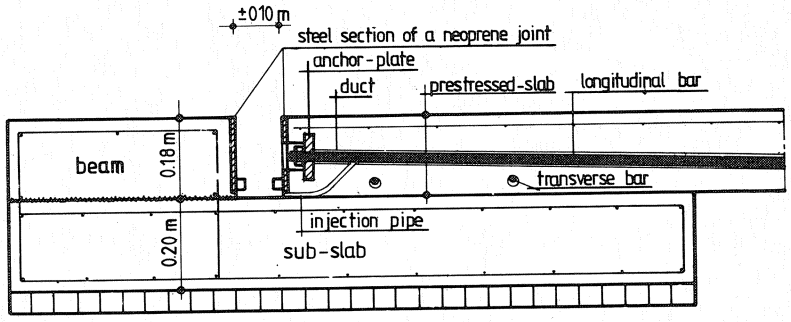


FIG. 7[b] CROSS-SECTION B-B (see also figure 4)

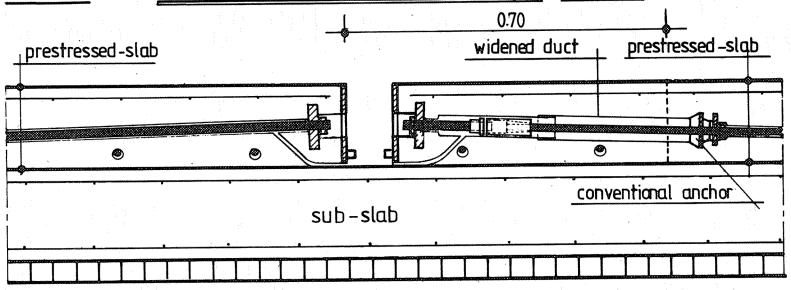
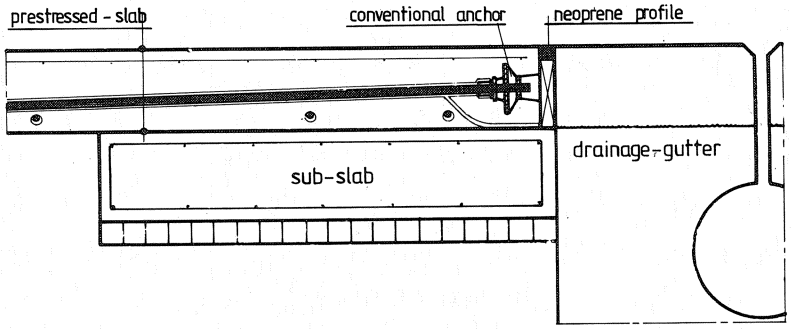


FIG. 7[c] CROSS-SECTION C-C (see also figure 4)



VII. Casting of concrete:

Before any activity with respect to prestressed concrete can be undertaken, an underlayer of 2 cm. sand asphalt must be used to create a smooth surface in order to reduce the losses in stressing due to the friction between the sub soil and the concrete slab.
On this sand asphalt layer, rails for the concreting paving machine are laid which together with the edge shuttering from an unit. For the further reduction of the bottom friction, the sand asphalt layer is covered by asphalt paper having a layer of plastic sheeting. On this layer, the ducts for longitudinal stressing bars are laid out.
The casting of concrete is done with a conventional concrete paving machine manufactured by A.B.G., suitable for 7,5 m. wide pavement. This machine has a concrete spreader type BV590 and two concrete finishers comprising of a vibrating machine type VAS512 and a surfacing machine type VAZ513. After the pouring, the concrete slabs are sprayed with curing compound and by using a brush, undulating rubbed pattern is created on the slab surface. This is done to crate a rough surface.

In practise, the above-metioned machine can travel with a speed of about 20 m. per hour. Considering a long working shift per day, two slabs of 120 m. each and situated behind each other in length can be constructed giving total area of 1800 sg. mts.
Suppose that a project of constructing an apron has a 360 m length and 75 m. width. This can be divided as 3 slabs behind each other and 10 slabs next to each other. The machine will finish a lane consisting of 3 slabs. (including the displacement to next lane) in two working days. This means that the entire slab area can be concreted in 20 working days.

The reinforcing team, to place the total prestressing steel, must be large enough to work in synchrony with the casting works.

VIII Concrete:

The concrete for prestressed platforms should comply with following general specifications:
- High compressive strenght
- Resist the freezing
- Resist the high temperatures
- Resist the chemical actions of aggressive material
- Resist the materials for controlling freezing (against chemical and/of physical actions)
- Resist the wear and tear

It is a known fact, that the high compressive strength of concrete results in good resistance against freezing temperatures, wear and tear. For the prestressed concrete pavement, concrete having characteristic compressive strenght of 57,5 N/mm2 has been rised. This characteristic compressive strenght is defined as the strength which is exceded by at least 95% of all theoretically expected test results.
The qualities of basic raw materials required for concrete is not always the same and the composition of gravel and sand varies from job to job.
Roughly, following mixture should give good results: Cement: 350 kg/m3 Hoogoven B (B is a measure for the fineness of grinding), water: 145 litres/m3, gravel 5/30 : 53 %, gravel 2/5 : 17 %, sand : 30 %.
Due to the low water/cement ratio, this mixture is difficult to work with.
This can be improved by the use of plastifying admixture. Lot of care should be taken for the concreting of bay ends. This care is required because, the ends of the bays are provided with prestressing anchors, grouting pipes, anchoring of the joint profiles, extra reinforcement nets etc. At these points, extremely good compaction should be achieved to withstand the stresses developed due to prestressing.

The surface treatment of concreted slab directly after the casting is very important. Particulary, to avoid the plastic shrinkage of concrete, measures should be taken against the evaporation of water in the concrete. This can be achieved by spraing curing -compound on the concrete surface. To avoid the big temperatures differences resulting from the cooling of concrete surfaces in the initial stages, it is necessary to cover the surfaces with an insulation layer like strawmats. These mats can be removed the concrete is reasonably hard.

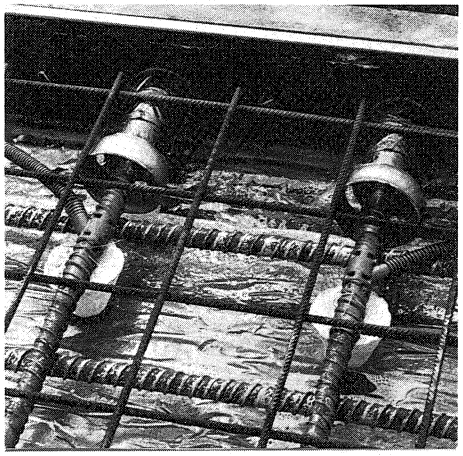


photo-5:

Anchoring end of transverse Lars

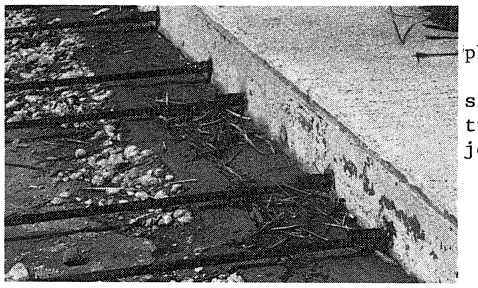


photo-6:

sleeve end at transverse joint

IX. Special construction details:

The required interruptions in the continuous pre-stressed concrete slab, at fixed points like avio-bridge foundations, fuel supply bits/hydrant systems, etc.; can be achieved by leaving the openings in the slabs during casting. The normal expansion joints are provided between the slab and the foundations mentioned above, to allow free expanding and shrinking of the slabs. These joints are shown on the photographs 9 and 10.

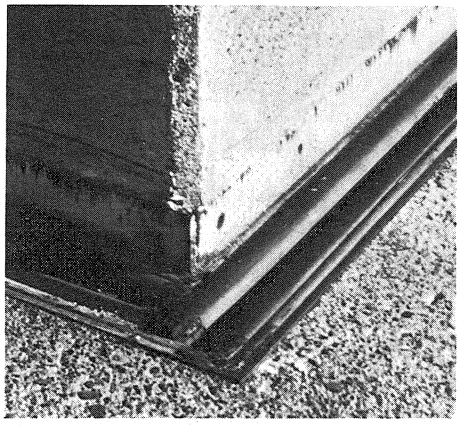


photo-7:

opening around a Aviobridge foundation with Acme-joint

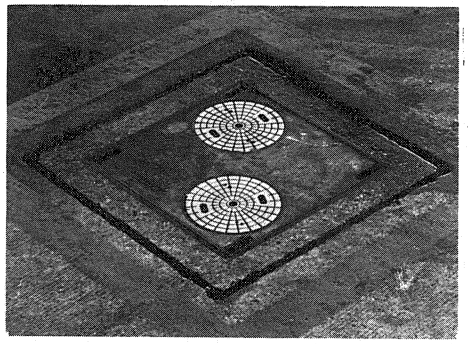
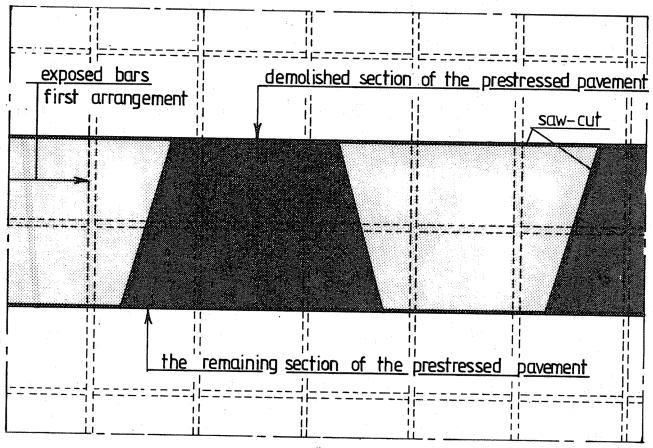


photo-8:

opening for hydrant pit with Acme-joint

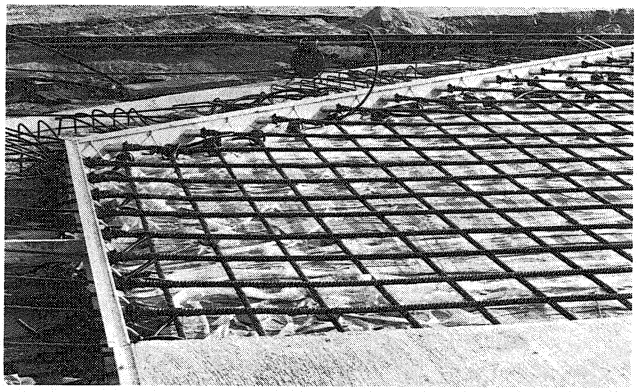
Cutting the opening in the existing prestressed concrete pavement is also possible. If one is sure of the quality of the grout injection, the opening can be made by using concrete saw without any problem. The anchoring of bars can be then achieved by grout injection. The tension will build up itself, completely, over 40 to 60 cm. length.
In case, one do not have complete faith in grout injection, the prestressing bars can be exposed by taking alternate trapezium shaped cuts in the slab and removing the concrete and the ducts over a bonding length. After cleaning the cut, the concrete is cast in it to have a good direct bondage between the concrete and the prestressing bars. After the hardening of this concrete, same operation is repeated for the alternate spaces left between the cuts. This operation is performed around the area of slab where the opening is to be made. (See fig. 8) The opening is made after the completion of above operation including the hardening of the concrete.

figure-8: Treatment of prestressing steel around the cut for the opening in existing pavement



An apparently difficult pavement layout, for example a hangarfloor, can be constructed by using pre-stressed concrete without any difficulty (see photo-11). Besides, three accessible passages have been provided in reinforced concrete under this hangarfloor for the aeroplane maintenance equipment.

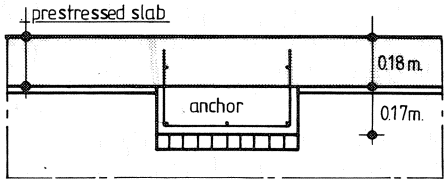
photo-9: Cornerdetail of hangarfloor



In case. it is required that the concrete slabs should expand or shrink in one particular direction only, then the slab is fixed by constructing a concrete anchor beam connected to and under the slab. (see figure 9).

figure-9:

concrete anchor beam



B. New developments:

I.General:

Although the results of constructing prestressed concrete pavement as described under A are very positive, the Technical services department of Schiphol airport is continuously looking for alternative methods having same qualities and which are more economic. The study has been made to use cables, instead of bars for prestressing. Initially unbonded prestressing cables were considered, but the extensive testing proved the risks involved in not injecting the cables and therefore this solution was descarded.

As the continuation of the above mentioned alternative studies, the injected prestressing cables were considered.

At the beginning of 1980, this system was used to construct a platform as a pratical test case, while today a complete project is being constructed by using prestressing cables. For this project, cables having Ø 12,5 mm. (consisting 7 wires) type F.E.B. 1860 are being used instead of Dywidag bars as mentioned previously.

photo-10: Anchors and joint profile of the cables

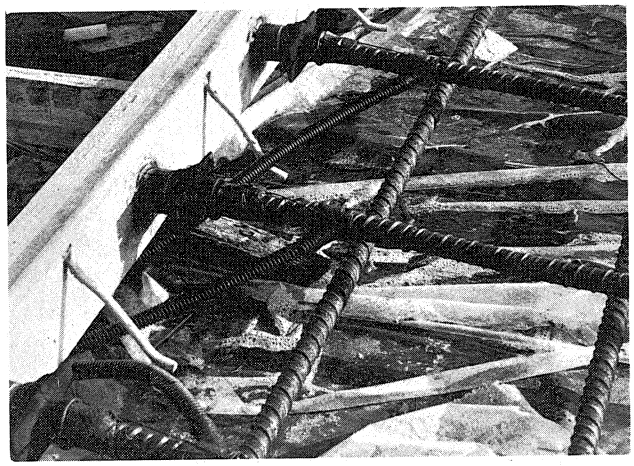


figure-10: Details joint between two slabs when prestressing cables are used

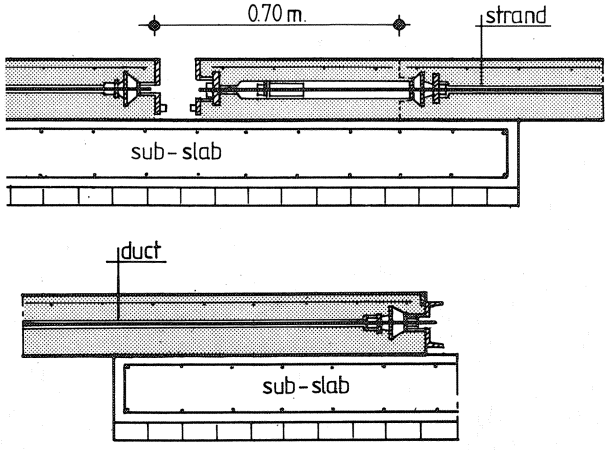
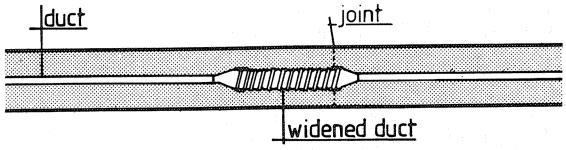


figure-11: Sleeve connection for the ducts of prestressing cables at transverse joint



II.Longitudinal cables (see figure-10):

The cables are rolled adjacent to the slab, which is to be cast, and are cut to a required length. The conventional duct is, then, pushed over the cable and the cable is placed in position munually. Simmilar to the prestressing bars, the profile of joint construction is used as an anchor block for the stressing. For this purpose, necessary holes are drilled in the profile and behind the profile, small pipe sections are welded around the holes. The pipessection is provided with a anchorplate having the wedges to anchor the cable. At the transverse joint between the ends of two slabs same problems, as those of using prestressing bars, arise. These are solved in the simmilar manners as in prestressing bars except that the final flat jack is not suitable for the cables. To overcome this difficulty, a prestressing bar is fixed to the cable end by the rise of coupling sleeve. This is done in 70 cm. opening between the two slabs. Hereafter same procedure, as per the bars, is repeated. Initially, the cables of slab B are stressed by using conventional anchores having blocking wedges.

III.Transverse cables (see figure-11)

To overcome the problems of pushing the bars through the transverse ducts, a solution of pulling the cables after casting of an area (number of bays next to each other) was considered. To do this, it is necessary that the ducts should be stronger to resist any eventual pressures of concrete during pouring, and also no flattering of circular ducts should occure since it will block the passage of cables afterwards. This is achieved by using a steel pipe of 25 mm diameter and 1 mm wall thickness instead of thin walled normal ducts. Another problem of placing cables in the ducts after casting of slabs is that of expansion or shrinkage of individual slab. The adjacent slabs may not have the same expansion or shrinkage. Specially at the ends of the long slabs, it can happen that the ducts of two adjacent slabs are not in one line. This will create a problem for pulling the cables after the casting of slabs. To overcome this problem, the ducts are enlarged at the ends so that after expansion or shrinkage of the slabs the ducts are reasonably in one line. The tests have shown that the displacement of 3 cm., with respect to each other, for the ducts does not involve any risks when the maximum expansion of a slab on side is about 2,5 cm.

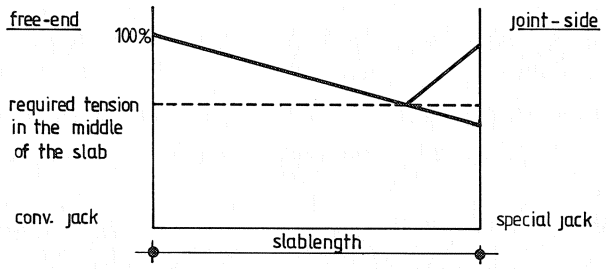
Although the cost aspects have been discussed at the later stage, it can be said that the use of cables reduce the price by about 20% per square metre for supply and installing the prestressing. This is mainly due to low prices for supply of cables and necessery parts and also due to low installation costs.

5. Further possibility of constructing the expansion joint between two slabs.

The optimum way of constructing an expansion joint would be:
- install and cats both joint-profiles in slab A and B
- carry out the full stressing at the free end of the slab in the previously mentioned stages using a conventional jack
- Stress up to 100% at the joint, using a special flat jack

See diagram below:

Figure 12 stress diagram



6. Further developments:

As a result of various considerations asphalt has been preferred as paving for taxi-ways and run-ways. During the past years serious doubt is grown regarding the durability of the asphalt pavements.
In this respect two main reasons can be mentioned:
a. the increase of the size of the loads, and more important b. the increase in the number of loads.

The effects of the above as observed in roadbuilding-practise are the track and wave-forming, mainly due to the stability of aspahlt, which results in a vertical movement of the surface layer.

The same problem appears on airfield, where the run-ways are constructed or asphalt. Track forming, however, still limited, tends to increase.
More serious for airfield surfacing is the horizontal movement of the asphalt layers as a result of the more frequent and heavier loads. The higher tire-gauges (12-13 kg/cm2) of the aircraft makes suitability of asphalt pavement for airfield more critical compared to roadbuilding. The possible increase of the tire-gauge in future, will result in asphalt being less attractive for airfields.
Clearly a strong increase in the maintenance cost of asphalt pavement is to be expected.
For the above reasons the Technical Department of Schiphol Airport has decided to apply concrete for the construction of the future taxi-ways.
In view of the favourable experience with prestressed concrete the choice of this surfacing-type has been made.
In future, also a renovation of one of the runways will probably be executed in prestressed concrete.
Therefore a study was started to examine the possibility of using a larger machine-width than the present 7,50 m.
A working-width of 11,25 m. would make it possible to construct a taxi-way in two and a runway in 4 lanes.

This study resulted in deciding to construct a taxi-way by above manner starting in April 1981.
For this purpose, the existing equipment will be adjusted to 11,25 m. by the supplier.
After consulting professor Eisenmann of the Technical University of Munich, it was concluded that the present tension-system needed to change.
A further investigation was made with respect to the "Schleppblech" joint, used in the past, because of the higher impact-loads that will influence the joints in taxi-ways.
This investigation and further experience at Cologne Airport with the present type, resulted in the choice of a new vere heavy design of the same "Schleppblech" joint, developed by Dyckerhoff & Widmann of Munich - West-Germany.

7. Design cretaria

I. Load-assumptions:
As load-basis, an aeroplane with a total weight of 300 ton, with a wheel-configuration of a DC-8 has been assumed in the past.
This resulted in a wheel-load of 32,75 ton. The total weight of 300 ton has been exeeded long ago by the present aircraft, however, the wheel-load of 32,75 ton is still up to date.
In association with a number of other European Airports and taking into account the present available information the Research and Development department of our airport has revised the present load-scheme.
Basis is now the wheel configuration of a DC-10-30 with a load of 130% of the total load of a present DC-10.
Fig. 13 shows the outcome of this configuration for the wheel-load, fig. 14 and 15 show the loads due to the use of a three-point jack, and a normal jack during changing a wheel.
Although the jack-loads are considerably higher than the wheel-loads, this is not alarming because of the far lower frequency of these loads.
Chapter 8. "Tests", shows that there is no harm to be expected from the purch-effect.

Figure-13

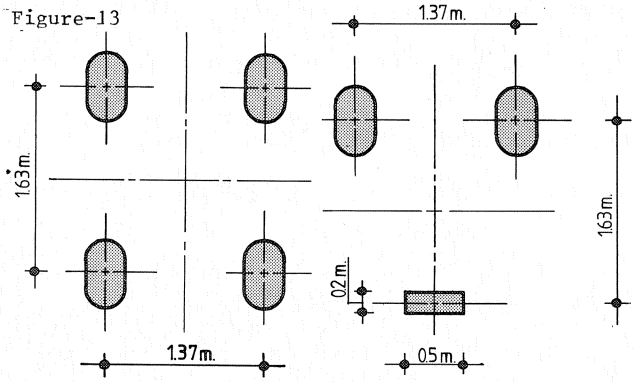
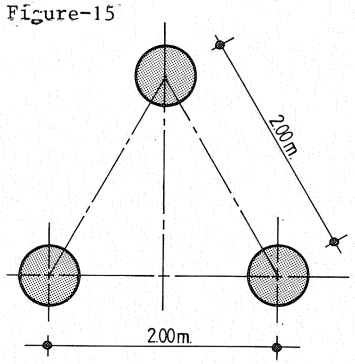


Figure-14



Load per wheel
P = 315 kN

Contact tire pressure
P = 1,30 MPa

Radius of contact area

R = 0,2776 m

II Temperature gradient:
Based on the expansion-coëfficient of concrete of 10-5 m/m°C and a temperature difference of max. 50°C, the maximum temperature gradient in the concrete by heating of the surface is 0,5°C/cm.

III Traffic-moments:
The traffic-moments are fixed by the use of the influence line cards of Pikett & Ray and corrected by Westergaard.

IV Prestressing forces:
Based upon the maximum permissible load, the nominal prestressing force in the critical slab section (always the middle section) is 8,8 N/mm2.
The losses to be taken into account in calculating the prestressing force are:
1- friction between stressed bar and the duct
2- tension loss by shrinkage or creepage
3- friction between the slab and the sub-base
Measurements have proven that the friction loss is 10% between stressing bars and ducts.
As a friction-coëfficient between slab and sub-base 0,5 is taken. (This in reality is favourable).
The prestressing force to be used on the longitudinal and transverse bars of Ø 15 mm is 730 N/cm2. This equals 132000 N per bar.
The required calculations and also the developments to make the Diwidagsystem suitable for pavement slabs have been carried out by Ir A.H. Kellersman of the Public-Works department of the city of Amsterdam, together with Dyckerhoff & Wismann - Munich.

8. Tests

In connection with the construction in 1973 of a railwaytunnel under the airport, a part of the existing presressed concrete apron had to be demolished.
This situation created the oppertunity to carry-out break and crack-loading tests. This has been done by a load-train which was given a weight up to 2 M N.

Firstly point-loads were introduced at 6 places by means of Ø 400 mm pressure plates. The contact area with the concrete slab was, in this way, almost equal to that of a Boeing 747 tire.
The tests on the following places
1- the middle of the slab
2- on the longitudinal joint
3- at a distance of 1,25 m from the gutter
4- near a corner of the slab
did not cause any collapse the maximum load of 1,8MN.
Only at the other two places, both directly next to the concrete gutter, crack due to negative moment appeared at 0,8 MN. The collapse-load at these places was about 1,2 MN.

After this a point-load by means of smaller plates (Ø 130 mm) was applied to the following places:
1- in the middle of a slab
2- on the longitudinal joint
3- at a distance of 1,25 m from the gutter.

In this case a clear crack was developed at 1,2 MN in the middle of slab and at 1,0 MN near the gutter. When the load on both was increased respectively to 1,8 MN and 1,2 MN the punch-effect occured.
Because of the fact, that the elastic deformation is limited a very short distance from the load, the maximum forces in the prestressed slab will be governed almost completely, by one wheel. (At the wheel distance presently used). This fact, combine with the resulting high break and crack loads proves that prestressed slabs can withstand the required loads.

9. Experience and Maintenance

A 15 years old experience in the application of prestressed concrete slabs around the fingers, at parking places, at the heads of runways, at the take off positions and for hangar floors has illustrated one important result:
"Zero maintenance"
This is mainly due to the small amount at joints with respect to the paved area, the use at a high quality joints, the high quality of concrete (which also insures a surface that remains rough) and the prestressing of the concrete (which prevents chrack-forming). The "Zero-maintenance" result provides, of course, an attractive financial benefit. However, to an airport the biggest advantage is the availability of the paved areas:
nosurfacing is out of service due to maintenance !
This has also its effect on the management and the operation of the airport service department because the non-availability of a part of the pavement gives an extensive amount of organisation work and thereto related costs.

The only required maintenance is the cleaning of the "Schleppblech" of the joint-construction, once in two years.

Should another type of pavement be laid adjacent to the stressed concrete (eg asphalt), then it is necessary to end the edges of the concrete with a small neoprence joint with a concrete beam or gutter as described earlier.

This is to avoid damage to the adjacent pavement caused by expanding concrete. Although no air-entrainers are used in the concrete, with respect to maintaining a high concrete-quality, it must be stated that the negative influence of chemicals to control freezing is negleetable.

This is in our opinion due to the high concrete quality and the very tightly controlled casting.

From the foregoing it can be concluded that the use of prestressed concrete slabs as pavement for airports is found to be very satisfactory at Schiphol-Airport, mainly due to the excellent durability of this surfacing type.

A warning is necessary, however, regarding the requirement of very accurate and controlled way of executing.
High demancy must be made on the contractor and the supervising personnel. It is important, at the same time, that the contractor who executes the works is familiar with the working-methods, if the best results are to be obtained.

10. Construction and maintenance costs

Investments on prestressed concrete pavement for an airport seems high, however, because of the positive cost effects due to the "Zero maintenance" it appears to be highly economic in practice.

To be complete, following rough cost indication per square metre of concrete pavement based on 1980 price-level is given:

- prestressing steel supply and fix	Dfl.	43.00
- concrete supply and fix	Dfl.	45.00
- stressing works (including injection)	Dfl.	12.00
- miscellaneous (joints, supporting slabs etc.)	Dfl.	20.00
Total cost of prestressed-concrete pavement per square metre based on minimum quantity of approx. 20000 m2.	Dfl.	120.00