PARTIAL RECONSTRUCTION OF THE RUNWAY AT STUTTGART AIRPORT – QUALITY MANAGEMENT DURING REMOVAL AND CONCRETE PLACEMENT

TEILERNEUERUNG DER START- UND LANDEBAHN AM FLUGHAFEN STUTTGART - QUALITÄTSSICHERUNG BEI RÜCKBAU UND BETONEINBAU

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SUMMARY

A partial reconstruction of the runway at Stuttgart Airport was undertaken in spring 2020. Thereby, the 1,200 m long eastern part of the 3,345 m long runway was replaced. The majority of the planes landing in Stuttgart use the eastern portion of the runway (Fig. 1). Such extensive use of the concrete runway built in the nineties of the last century resulted in ever increasing maintenance costs, finally rendering the reconstruction necessary. The present paper discusses some particular aspects of the reconstruction from the concrete technology standpoint and presents an overview of the quality assurance measures necessary for achieving a sufficiently strong and durable concrete pavement.

ZUSAMMENFASSUNG

Am Flughafen Stuttgart wurde im Frühjahr 2020 eine Teilerneuerung der Start- und Landebahn durchgeführt. Hierbei wurden im östlich Teil rd. 1.200 m der insgesamt 3.345 m langen Start- und Landebahn ausgetauscht.

Die meisten Flugzeuge setzen bei ihrer Landung in Stuttgart auf dem östlichen Teil der Start- und Landebahn auf (Bild 1). Die damit einhergehende nutzungsbedingte Beanspruchung der Mitte der 1990er-Jahre gebauten Betondecke hat zu einem steigenden Aufwand bei der Instandhaltung geführt, was letztlich den Austausch erfordert hat. Der folgende Beitrag schildert die Besonderheiten der Baumaßnahme aus betontechnischer Sicht und benennt die qualitätssichernden Maßnahmen zum Erreichen einer ausreichend festen und dauerhaften Betondecke.

Fig. 1: Aerial photo of the eastern part of the runway at Stuttgart Airport (source: Flughafen Stuttgart GmbH)

1. INTRODUCTION

The reconstruction of the eastern runway part at Stuttgart Airport commenced in April 2020 over a length of approx. 1,200 m and width of 45 m including the corresponding taxiways. Materials Testing Institute of the University of Stuttgart was involved in the project on behalf of the Stuttgart Airport already at the beginning of the planning phase. The main tasks were to advise the client both in the preparation phase as well as during the reconstruction of the airfield pavement to be built in concrete and to carry out acceptance testing required by the relevant regulations.

The given boundary conditions and the difficulties that occurred already in the preparation phase are described in section 2. In sections 3 and 5, several particular aspects with respect to concrete technology are reported and the quality assurance measures are described. Section 4 describes the construction phase. Here, Strabag Großprojekte GmbH was commissioned to replace the damaged concrete slabs on a total area of around 70,000 m². With a slab thickness of 40 cm, almost 28,000 m³ of runway pavement concrete of compressive strength class C 35/45 had to be laid.

2. BOUNDARY CONDITIONS

Since Stuttgart Airport has only one runway, the plan called for flight operations to continue only on a shortened interim runway during the construction work. In order to minimize the effect of construction on the flight operations, the damaged concrete pavements in the eastern part of the runway were replaced in two construction phases. During the construction period, only smaller aircrafts could use the shortened, western part of the runway, which is why only destinations up to approx. 1,400 km (1st construction phase) and up to approx. 2,800 km (2nd construction phase) could be reached.

Only 28 days were available for each of the two construction phases, which resulted in increased time pressure already from the beginning of the reconstruction. Particularly at the transition from the construction site to the existing building - in the so-called RESA area (Runway End Safety Area) - there was a very tight schedule because no work was permitted in this area under air traffic. Consequently, in the 120 m long RESA area (Fig. 2), construction work was only possible at night between 10 p.m. and 5:30 a.m. Furthermore, neither positive hindrances (elevations) nor negative obstacles (depressions) were allowed in the RESA area during flight operations, which means that all areas that were removed during one night must be concreted again the same night.

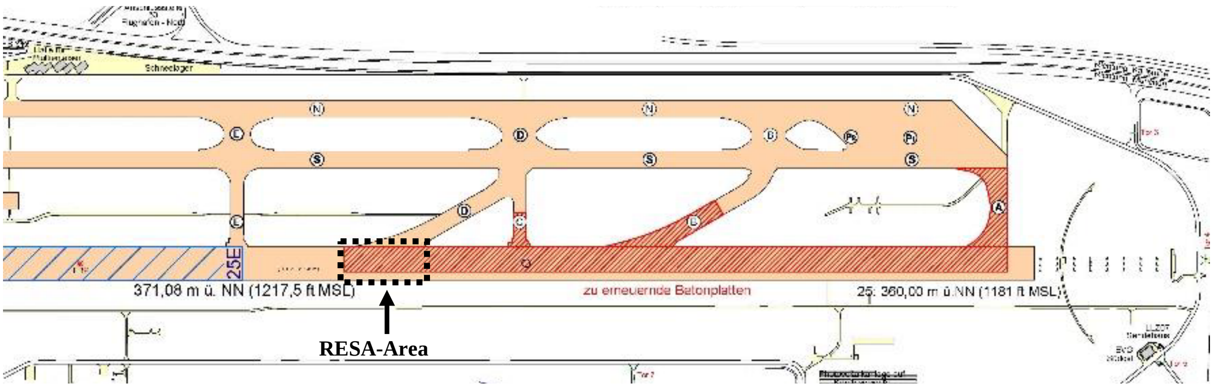

Fig. 2: Reconstructed area (hatched) with RESA-Area (Source: Flughafen Stuttgart GmbH)

The construction schedule was such that first the existing concrete pavements were to be removed over the entire 40 cm thickness up to the hydraulically bound base layer below. If necessary, the existing base course was to be repaired or compacted. After placing the dowel bar baskets and the tie bar baskets for joints, the concrete pavement should be placed in a single layer by means of a slipform paver. In order to avoid unplanned separation cracks in the joint area, it was important that the new longitudinal and transverse sawing joints were positioned exactly at the same locations as in the removed concrete pavement.

3. CONCRETE TECHNOLOGY

3.1 REQUIREMENTS ON THE CONCRETE

The newly paved concrete required - not only because there is only one runway available - a high load-bearing capacity, good surface condition and a high resistance to wear, as well as high durability. In terms of durability, resistance to damaging alkali-silica reaction (ASR) and resistance to freeze and thaw were of primary importance. On the basis of the relevant regulations [1-4], an air-entrained concrete of class C 35/45 with an increased requirement for flexural strength of at least 5.3 MPa was put out to tender.

3.2 CEMENT

Portland cement CEM I 42.5 N from a local cement plant was selected as the binder, according to the requirements of TL Beton-StB 07 [2] for the so-called road construction cement. The uniformity of the required properties was sufficiently proven by independent quality control.

3.3 AGGREGATES

Sand from the Upper Rhine was used as fine aggregate with a grain size 0/2 mm. Quartz porphyry (rhyolite) from the Black Forest was selected for the coarse aggregates up to 22 mm maximum grain diameter. Although the used aggregates are reported in the list of the Federal Highway Research Institute (BASt) as ASR harmless deposits with a passed initial or performance testing, further ASR performance tests were nevertheless necessary, due to other de-icing agents such as potassium or sodium formate used on air traffic areas instead of de-icing salt. As the ASR performance tests take a comparatively long time, extensive ASR tests were carried out in the run-up to the construction work using several de-icing agents commonly used at Stuttgart Airport in accordance with [5]. The approach for the evaluation of the freeze-thaw resistance of the aggregates is similar to that followed in the tests of TL-Beton-StB 07 [2] for de-icing salt. These tests are commonly used in concrete road construction; however they do not suffice as the unique evaluation criterion in case of attack by de-icing agents used at airports. Therefore, the evaluation of the freeze-thaw resistance of the coarse aggregate was carried out in the initial type testing with the de-icing agents commonly used at Stuttgart Airport. In addition, the freeze-thaw resistance of the aggregates was confirmed for concrete in the framework of the acceptance testing.

3.4 CONCRETE ADMIXTURES

The concrete pavement was produced with concrete plasticizer and air-entraining agent to ensure sufficient workability at the specified water-cement ratio ≤ 0.45 and to achieve a uniform air-entraining system for sufficient freeze-thaw resistance. The two admixtures came from one manufacturer and their effects were matched to each other through a combination test. In the initial test for the present project, the concrete with these admixtures was tested for its air void stability by measuring the air content of the fresh concrete at different times and for different durations of concrete compaction.

Due to the consistency of the pavement concrete and the use of concrete liquefying admixtures, the minimum air contents specified in TL Beton-StB 07 [2] (Table 1) must be increased by 1.0% by volume in the fresh concrete. This increase by 1.0% by volume is not required if suitable air void characteristics can be demonstrated on the hardened concrete in the initial test. The required limit values (micro air void content $A_{300} \geq 1.8$ vol.% and spacing factor $L \leq 0.20$ mm) on the hardened concrete were confirmed in the initial test.

Table 1: Minimum air content of fresh concrete acc. to [2]

Maximum aggregate size (mm)	Mean minimum air content for concrete (Vol.-%)
8	5.5
16	4.5
32 or 22	4.0

3.5 CONCRETE MIX AND MATERIAL PROPERTIES

Concrete composition and relevant parameters of fresh and hardened concrete - both for paver concrete and manually placed concrete - are summarized in Table 2. With the selected paving methods, the earth-moist paver concrete (consistency class C1) and the softer manually placed concrete (consistency class C2) were easy to process. The tests on the fresh and hardened concrete showed that all requirements on the concrete pavement were reliably fulfilled. The average concrete compressive strength of 57 MPa for the paver concrete was slightly higher than for the manually placed concrete at 52 MPa. The same applies to the average bending tensile strengths of 6.3 MPa for the paver concrete and 5.6 MPa for the manually placed concrete.

Table 2: Concrete composition and properties of the pavement concrete

Characteristic Material	Unit	Paver concrete Consistency C1	Manually placed concrete Consistency C2
Cement Cement content	 kg/m³	CEM I 42.5 N 360	CEM I 42.5 N 380
Water content w/c ratio	kg/m³	151 0.42	160 0.42
Aggregates Sand 0/2 Crushed stone 2/8 Crushed stone 8/16 Crushed stone 16/22	M.-%	 30 15 (12) [a] 25 (28) [a] 30	 30 15 25 30
Concrete admixtures Concrete plasticizer Air entraining agent	M.-% v.c.	 0.2 0.06	 1.2 0.02
Fresh concrete, mean values from the qualification tests			
Density Degree of compaction v_0 Air void content l_0	kg/m³ - Vol.-%	2330 1.27 4.9	2330 1.12 4.8
Air void values from the qualification tests			
Air void content A Micro air void content A_{300} Spacing factor L	Vol.-% Vol.-% mm	4.2 3.3 0.10	4.1 2.8 0.13
Hardened concrete, mean values from the acceptance tests			
Density after 28d Compress. strength after 28d Bending strength after 28d	kg/m³ MPa MPa	2360 57 (n = 52, s = 4.0) 6.3 (n = 15, s=0.5)	2320 52 (n = 14, s = 4.7) 5.6 (n = 2, s = 0,2)
[a] Concrete mix adjustments during the construction phase			

4. CONSTRUCTION PHASE

4.1 CONSTRUCTION PROCESS

As explained in Section 2, the time constraints and the limited space available for the work imposed additional organizational and safety difficulties, which needed to be overcome in order to place the concrete on time. Materials Testing Institute supported the client in overcoming these challenges by performing strength predictions on concrete, so that the newly produced areas could be released for construction operations in a timely manner. For this purpose, additional samples were produced as part of the initial testing for a strength prediction using the concrete maturity method. The compressive strength of the concrete can then be predicted during the construction process using embedded temperature sensors based on the temperature curve. The method of concrete maturity according to fib Model Code (2010) [6] was already successfully applied during our monitoring activities in the production of prefabricated tubbings [7, 8].

The intensive preparation phase, particularly for the night-time construction work in the RESA area, was partly cancelled, as flight operations at Stuttgart Airport were suspended between April 6 and 22, 2020, due to the corona crisis. On the one hand, this has considerably eased the construction process and it was possible to work in daylight. On the other hand, other difficulties arose since the construction project started earlier than originally planned. For example, the manufacturer of the coarse aggregate had to supply two major projects due to the fact that the construction work had been brought forward in time, which led to bottlenecks in the supply of aggregate size 2/8. In order to ensure that the paver-finishers were constantly supplied with concrete, it was decided, based on a concrete technology assessment, to slightly adjust the grain composition of the paver concrete (Table 2) in order to reduce the consumption of delivery grain size 2/8. This change in the mix proportion was minor and had no measurable effect on the concrete parameters of the monitoring of the contractor tests and the acceptance tests.

4.2 REMOVAL OF THE EXISTING CONCRETE PAVEMENT

The removal of the 40 cm thick concrete pavement slab was performed in several milling phases (Fig. 3). In order not to damage the hydraulically bound base layer below, the initial coarse milling passes were followed by a fine milling pass. The microstructure of the exposed surface of the base layer was then evaluated and, in cases of doubt, the load-bearing capacity was checked using a static plate load test (Fig. 4). After the surface had been released for concreting, metal baskets with plastic-coated dowels were positioned on the base layer.

Fig. 3: Milling machine for removing the 40 cm thick concrete slabs

Fig. 4: Measurement of the load-bearing capacity of the hydraulically bound base layer

4.3 CONCRETE MANUFACTURING

The concrete production was carried out on site with a mobile batch mixer type "BHS Duomix 300" (Fig. 5) and a mobile continuous mixer type "BHS Modulmix 200/3" (Fig. 6). In order to ensure a constant concrete quality, the continuous mixer was used for the production of the paver concrete only, while the batch mixer was used for mixing the concrete placed using the paver and for the manually placed concrete.

Fig. 5: Mobile batch mixing plant for the paver concrete and manually placed concrete

Fig. 6: Mobile continuous mixer type for the paver concrete

4.4 CONCRETE PAVING

The 40 cm thick concrete slab was paved with a 15 m wide paver. The concrete was manually placed only at the junctions of the taxiways to the runway and at reinforced slabs.

4.4.1 Paving using the slipform paver

The concrete was placed in one single layer in the previously milled strips between the existing tracks. The concrete, which had been transported with dump trucks, was first distributed by the excavator (Fig. 7). After spreading with the spreading plough, the concrete was compacted in the grout box in front of the slipform paver using vibrating rods. The compaction beam was used to level the concrete to the paving height specified by the side strips. The subsequent finishing beam, in conjunction with the super smoother, ensured the surface finish and final evenness (Fig. 8). From the trailing working platform, the broom finish was applied with a steel broom to improve the initial grip and the liquid curing compound was applied to the pavement surface.

Fig. 7: Slipform paver. Distribution of concrete with an excavator

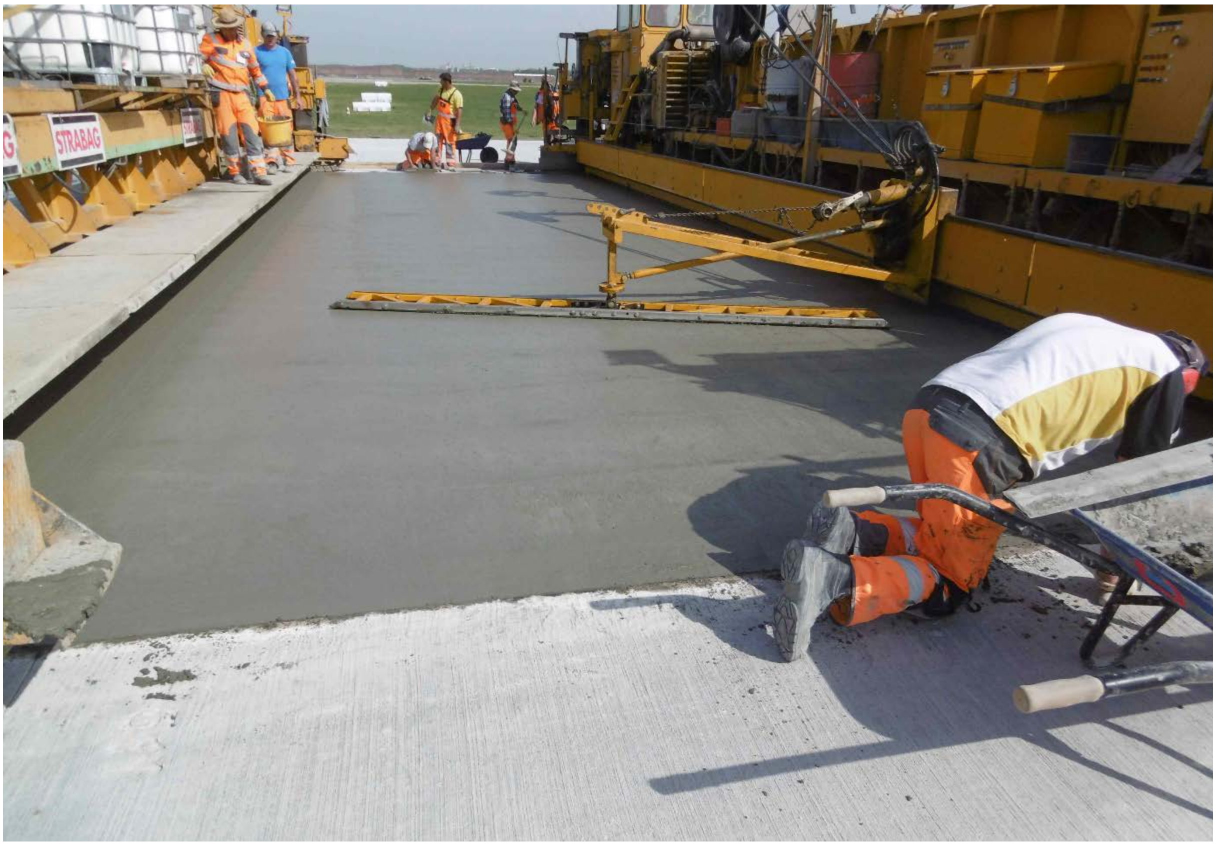

Fig. 8: Finishing beam and super smoother for the finishing of the pavement. Trailing working platform used for the application of the broom finish

4.4.2 Manually placed concrete

The concrete was placed in single layers in small, partially reinforced individual fields. The concrete, delivered by truck mixers, was delivered directly to the paving site via the discharge chute (Fig. 9). After distribution with an excavator, the concrete was compacted using vibrators. A vibratory truss screed guided at the edges was used for surface finishing. After the broom finish was produced, curing agent was applied.

Fig. 9: Manual concrete placement

5. QUALITY ASSURANCE MEASURES

The quality assurance of the concrete was based on the requirements from [1] and [2], consisting of initial type testing, contractor testing and acceptance testing (Fig. 10). The test procedures, test frequencies and responsibilities contained therein were concretized and partly supplemented in a quality assurance plan to meet the special requirements of the present construction project. Among other things, the quality assurance plan described that so-called test mixes are to be carried out after presentation of the initial test results and after installation of the two mixing plants. The timeline was laid out so that, if necessary, potential problems could be addressed before the construction began. In order to establish confidence in the results of the contractor testing and acceptance testing, the tests on the test mixes were carried out simultaneously. In addition to the usual acceptance testing, further properties were measured during the construction work, such as the measurement of the texture depth on the concrete surface with a laser-based texture depth meter (Fig. 11).

Fig. 10: Acceptance testing at the paving site

Fig. 11: Measurement on the concrete surface with a laser-based texture depth meter

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