Slipform Paving Concrete

Airfield

Construction Preparation

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Introduction

- Airfield paving is a high stakes game because of performance specifications and thick airfield slabs require careful attention to concrete mix design, uniformity and strength.

- Careful planning during the bid stage and prior to construction can mitigate many of the inherent risks.

- The “GORY DETAILS” make the difference between a good job and a bad job.
Items to Consider In Preparation for Slipforming Concrete Airfield Slabs

- Establish the Equipment to be Used
- Selected the Proper Equipment
- Establish Your Paving Pace
- Mix Design – Use a Well Graded / Optimized Mix
- Concrete Uniformity
- People
- Innovation
Establish the Equipment to be Used

- The **KEY** is selecting a slipform paver of sufficient weight and structural rigidity to withstand the lifting forces of low slump concrete and thick slabs at high production rates.

- It is recommended to use a slipform paver (for thicker airfield paving) that is approx. 85,000 lbs (38,460 kg) or more.

- With a heavier paver, you can dump on grade in front of the paver with only minimum risk of overloading.
Establish the Equipment to be Used

If the paver is too light there is little room for error. When the machine is inadvertently overloaded *(which does and will happen!)* you don’t have sufficient weight / traction to get you through the overload…and machine will spin out. If this happens:

- The paver won’t be able to hold grade
- The paver won’t be able to hold line
- Edges will be adversely affected (wavy)
Establish the Equipment to be Used

A “lighter” slipform paver of less than approx. 60,000 lbs (27,150 kg) should not be used for thick airfield paving unless the concrete is carefully pre-spread and metered to the slipform paver to avoid overloading! To minimize overloading carefully pre-spread by using:

- a front end loader or excavator with spreading bucket or
- a Placer Spreader or
- a Placer and spreading with the Placer swing conveyor.

CAUTION: SOME PLACER SPREADERS CAN BE EASILY OVERLOADED WHEN USING VERY LOW SLUMP CONCRETE WHICH CAN SIGNIFICANTLY REDUCE PRODUCTION AND CAUSE FREQUENT, UNDESIRABLE STOPPAGES!
Airport Paving is a HIGH STAKES Game. Spend the time and money to prepare your equipment for paving:

- Thoroughly clean and service. Dried concrete in the liquification hopper especially in the corners can inhibit good edges.

- Repair bent or damaged sideforms or edgers or they will inhibit sharp edges and cause unexplained imperfections in the concrete surface profile.

- Rebuild or Replace Vibrators
Make Sure Selected Paver is in Good Condition

- The paving kit sections bolting connections must be properly torqued and the kit solidly connected to the tractor frame to withstand the effect of low slump concrete and a thick slab wanting to lift the paver. These forces will have an adverse effect on slab smoothness and slab alignment.

- The slipform pan must be perfectly flat without any bellies or dips in the pan skin. These imperfections can cause localized concrete pumping which adversely affects slab smoothness.
Make Sure Selected Paver is in Good Condition

It is also important that all mechanical connections from the crawler tracks up to the jacking columns are “tight” to minimize slack or backlash that can adversely effect the machines ability to steer properly under the high loads found especially on thick slabs.
Make Sure Selected Paver is in Good Condition

- The paving kit sideforms should be vertical and not battered to avoid any risk of acute angle cracking.
Establish Your Paving Pace

- When paving thick airfield pavements you must produce sufficient concrete and have sufficient trucks to supply the paver to avoid “stop and go” paving.
- Stopping and starting the paver while paving is undesirable and will adversely affect your edges and surface profiles. For best results, the “goal” should be to pave at a constant speed and AVOID STOPPING.
Establish Your Paving Pace

- Thick concrete slabs consume a lot of concrete per lineal foot (meter). Ideally you need sufficient concrete production out of a **single plant** to maintain a steady paving speed of at least 3 to 4 fpm (0.9 to 1.2 Mpm.)

- Although it is possible to supply concrete out of two plants to match your needs (such as on two lift construction), the best practice in order to control concrete uniformity (slump) is to supply all the concrete from a single plant.
Establish Your Paving Pace

Calculate the Concrete Supply Requirements:

- For 25' (7.6M) wide paving x 20" (0.5M) thick concrete, your volume is 25 x 20/12 = 41.7 cubic feet / 27 cubic feet/cyd = 1.54 cyd / lineal foot.

- If we are shooting for the ideal paving pace > 3 to 4 fpm: 1.54 cyd / lineal foot x 4 fpm = 6.16 cyd / minute x 60 minutes / hour = 369 cyh practical concrete plant output. Most good USA contractors can achieve a job average efficiency of 75%. Thus the plant needs to have a peak output of 369 cyh / .75 = 492 cyh.
Establish Your Paving Pace

- To achieve this production rate: Plant with tilting drum mixer takes two mixers or a mixer with a “shrink drum”. Normally at least 60 second mix time is required to achieve mix uniformity with airport slump concrete.

- To achieve this production rate: Plant with twin shaft mixer (compulsory) takes a single mixer (single batch per load). Normally at least a 45 second mix time is required to achieve mix uniformity.
Establish Your Paving Pace

➤ You must have a sufficient number of concrete hauling trucks to sustain this paving pace and to match your plant output.

➤ Other logistical issue must be considered and planned to sustain the paving pace such as sufficient on site storage of cement, aggregate, cure, etc.
Concrete Mix Design Planning

Mix Design isn’t just about strength and how much cement is in the mix. Combined aggregate gradations and particle shape must be considered to achieve superior concrete slabs, smoothness and edge quality. Of course available local aggregates must be considered.

- Use well graded coarse and fine aggregates. You must look at the combined gradation (in lieu of just the individual gradations) to ensure durable and workable concrete that isn’t too fine or coarse for paving.

- Crushed aggregates with good particle shape work best in concrete pavements as opposed to river rock.
Well Graded Aggregate Mixtures

Single-Sized

Gap-Graded

Well-Graded

Use of Aggregates and Water for Concrete by Rick Bohan, Portland Cement Association, Skokie, IL
Well Graded Aggregate Mixtures

Shilstone gives the analogy of “building a stone wall” which helps us visualize well graded aggregates and a stable mix.

- Construction of a stone wall is comparable to a concrete mixture.
- The mason selects large stones and fills the major voids with progressively smaller stone to stabilize them and bonds them together using mortar.
Particle Shape & Surface Texture

- Rough-textured, angular, elongated, flat particles have higher water demand requiring more mortar to fill the voids than smooth, rounded or cubical aggregate to achieve a workable mix.

- Typically the only way to increase the workability of a mix is to increase the fine aggregate to increase the mortar.
Well Graded Aggregate Mixtures

- Volume of paste (cement + water) to fill voids plus some for workability
- Well graded aggregates with good particle shape reduce voids thus water demand is lower
- Lower water demand minimizes mortar / paste requirement thus less cement is required for a spec’d W/C ratio to reach strength
  - Reduced cost
  - Reduced temperature rise
  - Reduced shrinkage
  - Reduced permeability to avoid sulfide and chloride attack
  - Reduced risk of spalled joints
Most two aggregate mixes using an ASTM #67 or #57 Stone and a C-33 Sand have a double humped combined gradation curve, typically deficient in retained #4 and #8 rock. This gapped or nearly gapped graded mixture can result in overly sandy or coarse gap graded mixtures which are undesirable for durable airfield pavements.
Combined Gradation – Gap Graded / Double Humped Curve

Percent Retained

Sieve

1 1/2" 1" 3/4" 1/2" 3/8" #4 #8 #16 #30 #50 100 200 325 Liq Pan
Combined Gradation – Well Graded / “Shilstone” Curve

Percent Retained

Sieve

1 1/2" 1" 3/4" 1/2" 3/8" #4 #8 #16 #30 #50 100 200 325 Liq Pan
Coarseness Factor Chart

Notes:
1. **Coarseness Factor** = \( \frac{\text{% Retained Above } 3/8" (9.5mm) \text{ Sieve}}{\text{% Retained Above } #8 \text{ Sieve}} \times 100 \)

2. **Workability Factor** = \( \text{% Passing } #8 \text{ Sieve} \)
Gap vs Well Graded Mix

1988 Gap Graded
1929 Dense / Well Graded
Well Graded Aggregate Mixtures

Steps to achieve well graded aggregate Mixtures:

- Optimize your Mix! Look at combined gradations and re-proportion aggregates to achieve a well graded “Shilstone” mix using the Coarseness Factor Chart.

- If by re-proportioning you cannot achieve a well graded mix you may need to add an additional aggregate.

- Use the “Tarantula Curve” for plotting retained aggregate gradations as another tool to help predict the impact of gradations on how concrete will finish.
Well Graded Aggregate Mixtures

Steps to achieve well graded aggregate Mixtures:

- Hold your gradations at each sieve size within a narrow band. The coarseness factor chart is just a snapshot in time!

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Mix Design

With well graded aggregates:

There is less likelihood that the mix is too coarse and gap graded where large stones get tumbled when forming edges or finishing the slab surface.
Mix Design

With well graded aggregates:

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- There is less likelihood the mix is too fine (too much workability) where there is too much mortar on the surface.
- Excess mortar on the surface may spall in the future.
- Try to hit close to the target on the Coarseness Factor Chart.
Be Careful of Too Much Surface Mortar
Be Careful of Too Much Surface Mortar
Mix Design

Using well graded aggregates with good particle shape will yield dense, durable and workable concrete. With these types of mixes:

- There is less likelihood of finishing issues
- Vibration is transmitted more easily achieving better consolidation and fewer voids in the slab
- You can typically achieve smoother pavements
- There is less chance for joint and surface spalling
- There is less chance for edge slump
Mix Design

The time to plan to achieve well graded aggregates is

- Prior to bidding the job
- Or at least before you place the order with your aggregate supplier
- **ONCE YOU HAVE STARTED PAVING AND EXPERIENCE MIX PROBLEMS IT IS VERY EXPENSIVE TO CHANGE YOUR GRADATIONS**
Mix Design – Aggregate Stockpiles

Aggregate producers and contractors need to plan their material handling process and stockpile management program at the crusher and the concrete plant (at the job site) to avoid dirty / contaminated or dusty aggregates.

- This planning must be done prior to the start crushing or mining.
- Mix abnormalities such as slab finishing, slumping edges, cracking, voids, and loss of strength, can be due to dirty or dusty aggregates.
Mix Design - Dirty Aggregates

- Aggregates with 8% or more passing #200 (75 μm) sieve are considered dirty. The dirt or rock dust is many times found in lenses in the stockpiles.

- Clay balls in your aggregates can create pop-outs in the slab surface. Clay balls rise to the concrete slab surface under vibration. When clay washes out, a void on the surface will result.
Mix Design - Dirty Aggregates

- The “dust” or “dirt” on the rock represents additional fines that draw moisture from the mixture and decreases workability.

- Lenses of dirt in the stockpile will make it almost impossible to control concrete slump/uniformity.

- The lighter fine material may rise to the surface during consolidation in the form of dirty “bleed water”. These areas can lead to plastic shrinkage and cracking problems.
Mix Design - Dirty Aggregates

Finishers describe concrete made with dirty aggregates as difficult to finish or “gritty.” At low slump, this concrete tends to tear on the surface as it leaves the slipform pan.

The drying shrinkage may also increase, particularly if the crew adds more water to compensate for the mixture’s poor finishing properties.
Threshold hand lay shows bleeding dirty aggregates
Concrete made with dirty aggregates tend to develop less strength than is expected from job mixture trials. A loss of as much as 1,500 psi (10.3 MPa) compressive strength can occur. Strength loss is due primarily from lack of bond between the paste and aggregates due to dust coating.
Concrete Uniformity – Two Types

UNIFORMITY - within each concrete batch:
Thorough and complete mixing of all the batch ingredients into a homogeneous mass is necessary to achieve uniformity.

UNIFORMITY - batch to batch:
Accurate weighing and slump control. Slump control is achieved by good stockpile management, clean uniform sand and aggregates, a good loader operator, moisture sensors, a good plant operator, and accurate weighing of all ingredients especially sand, water and cement.
Concrete Uniformity

CONCRETE UNIFORMITY - within each batch AND batch to batch is achieved by proper planning:

- Use of a modern concrete plant with modern computerized controls.
- Not exceeding the batch size intended for the mixer on the plant
- Thorough and complete mixing – mixer uniformity test to determine the mixing time that yields uniform concrete
- Select a workable concrete mix that doesn’t tend to segregate
- Follow good stockpile management practices and train your loader operator. Have a three days supply of aggregate at the plant site so stockpile moisture can stabilize.
Concrete Uniformity – Manufactured Sand

- Washed / Clean Natural Sand yields better concrete workability and results in more uniform sand moisture in the batch making it easier to control slump/uniformity.
- Manufactured Sand (if NOT devoid of rock dust) makes the concrete more difficult to mix uniformly and hard to control slump. It must be uniform. Mixing times need to be longer to get good cement dispersion reducing production rates.
- Manufactured Sand demands more water thus requires more cement paste to achieve workability than Natural Sand.
Aggregate Cross Contamination and Rock Dust Contaminated Manufactured Sand
Clean / Uniform Natural Sand
Clean / Uniform Intermediate Size Aggregate
Dividers between Aggregate Bins Prevent Cross Contamination
Aggregate Stockpiles Cross Contamination Avoided Using Barriers
Concrete Uniformity - Slump

- Very tight concrete slump control must be maintained when paving thick airport slabs. G&Z likes to see contractors attempt to hold the slump to $\pm \frac{1}{4}''$ (6mm).

- Concrete slump on airfield pavements is typically $\frac{1}{2}''$ to $1''$ (12.5mm to 25 mm) range. The mix design, gradations, particle shape, ambient temperature and humidity will dictate the lowest slump that can be paved and still have workability.
Concrete Uniformity - Slump

One cannot talk about slump without addressing the uniformity and workability of the concrete mix.

- The less workable the concrete and harder to finish, the higher the slump required in order to consolidate and finish/close the slab surface.

- The higher or more variable the slump, the more difficult it is to produce concrete slabs without edge slump.

This “Catch 22” dictates you need well graded, uniform concrete for success in paving thick airfield pavements.
A Uniformly mixed / well graded concrete mixture is one of the KEYs to successful airfield paving!
Without an experienced, motivated and conscientious paving crew, committed to superior quality, from the management to the concrete finishers, obtaining superior airfield slabs will be difficult.

Proper pre-bid / pre-job planning is absolutely necessary!
People write the airport paving specifications. Contractors, the industry and the specifying agencies should start working together PRE-BID to review specifications for best cost and performance.
Conclusion

- Proper Equipment
  - Equipment with sufficient weight that is clean and in good working condition

- Paving Pace
  - Pave at a constant speed & NEVER STOP. Match plant output and trucks to paving requirements.
Conclusion

- Good Mix Design
  - Well graded aggregates / Good particle shape / Concrete uniformity and workability

- People
  - Experienced, motivated and conscientious people, committed to superior quality, from the management to the concrete finishers, is essential.
  - Contractors and specifiers must work before and after the job is awarded to achieve superior airfield pavements
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