ACRP Problem Statement: 382

Optimized Aggregate Gradation and Performance-Engineered Mixtures for Airfield Concrete Pavement

Recommended Allocation: $500,000

Tags: Construction, Design, Sustainability

Thought Leader Forum on Emerging Issues: N/A

Research Roadmaps: N/A

Staff Comments

Performance-related research for airfield pavements has traditionally not been a topic undertaken by ACRP. The funding amount appears appropriate for research that includes field work.

AVERAGE INDUSTRY RATING BY AUDIENCE SEGMENT

Audience Segment	Average Rating	Number of Responses
Academicians	4.67	3
Airline Representatives	N/A	0
Airport Employees	4.00	1
Consultants	3.50	4
Fed/State/Local Government Employees	1.00	1
Private Sector	5.00	1
Undefined	5.00	2
Overall Total	3.86	12

AOC Disposition

The average AOC rating among voting members was **3.1** on a scale of 1 to 5. The problem statement was brought up for discussion. The research is important, yet FAA can undertake it. The problem statement was not selected for ACRP funding and will be returned to the idea collection stage of ACRP's IdeaHub.

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Summary

The proposed study is to incorporate the latest concepts of optimized aggregate gradation and Performance Engineered Mixtures (PEM) that have been successfully used in highway pavement to improve airfield concrete pavement design procedures. The goal of the study is to maintain desirable engineering performance and produce long-lasting airfield concrete pavement while promoting contractor innovation in the mix design process. The study is to be composed of a systematic theoretical and experimental analysis of aggregate gradation and particle packing to determine the most appropriate aggregate gradation optimization approach for different airfield pavements. Proper fresh and hardened concrete performance evaluation methods for airfield concrete pavement will also be developed or identified inspired by PEM concepts adopted by the highway pavement industry.

Background

In the last few decades, Federal Highway Administration (FHWA), Department of Defense (DoD), and Federal Aviation Administration (FAA) have been following the guideline presented in US Air Force Engineering Technical Letter (ETL) 97-5 (Proportioning Concrete Mixtures with Graded Aggregates for Rigid Airfield Pavements) for concrete aggregate mix design. The combined aggregate retained "8-18" graph, workability box (coarseness factor/workability factor), and 0.45 power grading chart are typically used to obtain desired combined aggregate gradation. Multiple new theoretical and experimental methods have been recently developed for aggregate optimization for highway concrete pavement design. The Tarantula curve, which was developed based on a large amount of highway pavement data, has been quickly adopted in the highway pavement industry and state highway agencies. However, as airfield pavement has a greater thickness and lower water-to-cement ratio (w/c) compared to highway pavement, it is questionable if an empirical approach such as the Tarantula curve is the most appropriate for airfield pavement.

Recent experiences have shown that the Tarantula curve could result in an excess amount of fines in airfield pavement, which could lead to a segregated mortar rising to the pavement surface and result in silver spalls and other issues for airfield pavement. This can be a significant problem because of the potential Foreign Object Debris (FOD) damage to the engines of aircraft. Existing aggregate optimization methods rely solely on aggregate gradation. However, critical aggregate characteristics, such as aggregate shape and surface textures, are often not considered. An inappropriate airfield pavement design could lead to edge slump, which is critical for airfield pavement with a thickness as high as 15-in or more. A recent study showed that in addition to the theoretical ("paper") analysis of aggregate gradation, experimental approaches such as the combined void content of aggregate could be adopted to achieve a more rational concrete pavement design. With the new approaches and recent experiences in airfield pavement design, there is a need to evaluate the effectiveness of traditional and new methods and determine the most appropriate technique(s) that can be used to further optimize the aggregate gradation for airfield pavement. A systematic study that incorporates both theoretical and experimental approaches is warranted to determine the best method(s) for aggregate gradation optimization and rational concrete mixture design for airfield rigid pavement.

While the quality control of airfield pavement has been largely relying on traditional test methods such as slump, air content, and strength, these tests do not always prevent common issues associated with airfield pavement, such as edge slump, silver spalls, scaling and surface spalls. With recent advancements in testing technologies, the highway pavement industry developed a series of new performance evaluation tests, including Box test, V-Kelly test, and formation factor test to ensure appropriate construction, mechanical behavior, and durability performance. However, as airfield pavement is largely different compared to highway pavement, there is a need to identify or develop appropriate test

methods for airfield pavement. Particularly, it will be beneficial to develop an airfield concrete workability test to ensure appropriate workability and constructability. Performance requirements and how to incorporate key performance parameters into a robust specification and quality process for airfield pavement is also needed.

Objective

The overall goal of this study is to develop a guideline to help airfield practitioners adopt the best method(s) for airfield rigid pavement mix design and performance evaluation. To achieve this goal, two specific objectives are to be included: 1). Identify an aggregate gradation optimization method with critical control points (such as boundaries for gradation curve) to promote successful airfield pavement construction and performance, and 2). Determine key performance evaluation methods to verify appropriate fresh, hardened concrete, and durability performance of airfield pavement concrete. The optimized aggregate gradation and concrete performance data will set a baseline for the concrete mix design approach and performance evaluation for airfield concrete pavement.

While the current airfield pavement concrete design specifications provide excellent mixes and placement, the prescriptive procedure sometimes makes it challenging for airfield pavement contractors to achieve an optimum design. The purpose of the study is to allow more contractor innovation by incorporating performance-based concepts and simplify the design process yet still able to maintain equal or better airfield pavement performance. The success of the study will lead to recommendations and guidelines for airfield concrete pavement practitioners to optimize airfield concrete mixture for better engineering performance.

Research Approach

In order to achieve the above-mentioned objectives, five major tasks should be included in the proposed study:

1. Survey and data analysis. The research team will collect aggregate gradation, concrete mix design, and performance data from representative airfield pavements to evaluate the effectiveness of different aggregate gradation control methods on concrete performance.

2. Aggregate gradation optimization. Besides evaluating and identifying the most appropriate theoretical ("paper") gradation criteria, an experimental packing method will be used to assess the gradation of aggregate as well as the resulted aggregate packing degree.

3. Performance evaluation. Tests specific for airfield pavement could be developed based on the modification of current test methods that are commonly used in PEM for highway concrete. Key mixture parameters will be identified to assess whether or not the optimized aggregate gradation will result in airfield pavement mixtures with satisfactory workability, mechanical properties, and durability performance.

4. Field performance evaluation. Conduct field tests at two different airports to evaluate the constructability and performance of the developed mixes with optimized aggregate gradation.

5. Recommendation and guideline. The research team will work closely with FAA and the DoD to develop/update guidelines for aggregate gradation optimization, concrete mixture proportioning methods as well as performance evaluation methods for airfield concrete.

Cost Estimate/Backup

Recommendation allocation of $500,000 for a 24 to 30 months study to complete the necessary survey, experimental work, data analysis, and recommendation and guideline development associated with the proposed study. Besides laboratory studies, field testing is an essential part of the study. The research team will need to identify one or two

airports that will help support the field study to evaluate the constructability and performance of the developed mixes in real field conditions.

Related Research

While traditional methods such as combined aggregate retained (8-18) graph, workability box (coarseness factor/workability factor), and 0.45 power grading chart have been used over the last few decades to obtain desired combined aggregate gradation, several new methods have been recently developed to optimize aggregate gradation. One example is the Tarantula curve that has been successfully incorporated in highway concrete pavement mixtures (Ley and Cook 2014, FHWA TPF-5(286)). However, recent experience indicated that the approach is not necessarily the best for airfield pavement, owing to the edge slump issues as well as silver spalls and scaling from the high fine content. A recent study from Nebraska Department of Transportation (DOT) (Mamirov et al. 2019, SPR-P1(18) M069) indicated that a combination of theoretical and experimental aggregate packing study is more appropriate to ensure optimum aggregate gradation and a rational mix design approach. Results from the study showed that when optimum gradation is used, cement content could be reduced up to 94 lb/yd3 (56 kg/m3) with satisfactory key fresh and hardened concrete properties. Additional research is needed to evaluate new aggregate optimization methods for an airfield environment.

A recent PEM study led by the National Concrete Pavement Technology Center identified a set of critical concrete mixture performance tests that can be successfully used to verify appropriate fresh concrete, hardened concrete, and durability properties for highway pavement (Taylor 2018, FHWA TPF-5(386)). However, a systematic study is needed to evaluate these PEM concepts for use in an airfield environment since airfield pavement has different needs compared to highway pavement, are typically mixed at a lower w/c ratio, and are placed at greater thicknesses.

References:

1. Ley, T., and Cook, D. (2014). "Aggregate Gradations for Concrete Pavement Mixtures," CP Road Map, Moving Advances into Practice (MAP) Brief. FHWA TPF-5(286).
2. Mamirov, M., Hu, J., and Kim, Y-R. (2019). "Evaluation of Reducing Cement Content in NDOR Class R Combined Aggregate Gradations." NDOT Research Report SPR-P1(18) M069.
3. Taylor, P. (2018). "Performance Engineered Mixtures for Concrete Pavements," Tech Brief. FHWA TPF-5(386).

Author: Jiong Hu, Associate Professor, University of Nebraska, Lincoln

INDIVIDUAL COMMENTS FROM THE INDUSTRY REVIEW

Airfield pavements are the most important and typically most expensive projects on an airfield. Any study that further examines more pavement design options is welcomed.

Applicable, achievable, and implementable:

Data gathering could be a weak point, because it relies on airports & consultants to respond to surveys by providing detailed concrete design data, which requires a deep dive into their files. Implementation relies on FAA to accept the study results.

Good topic, the field studies will be valuable. I think one key to this will be laboratory performance testing however, as a two-year field study won't likely differentiate many properties of trial PCC.

I believe the current concrete specifications in place for airport facilities is sufficient. Using current specifications and best practices for construction, design, etc., there is no reason that the facilities built today will not last for many many years.

It is essential to optimize the mix designs of each concrete depending on the performance required. Field testing is a good approach to take in evaluating the performance of different mix designs. Not only the aggregate gradation needs to be taken into account, but also the type of aggregate locally available at the given airport. Therefore, it would make sense to allow for some more flexibility in gradation depending on aggregate type, rather than determining one set gradation in the specs/guidelines. Very interesting and important topic.

This is a very useful and practical research that can be of benefits to airport pavement by optimizing the aggregate gradation. Some other considerations such as recycled aggregate could be included; and field performance of projects only have two, which seems to be low.

Very applicable problem statement as aggregates vary from location to location. A discussion of a potash replacement should also be included.

Very thorough proposal. Important topic for the airports, operators, and manufacturers. Being on the cutting edge and making improvements to pavement can improve airport design and operations. Boeing Airport Compatibility Engineering may like to be involved, as pavement in airfields around the world is one of the main areas of our work statement.

Well developed problem statement. It would beneficial and applicable to many airports.

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Input Provided by ACRP IdeaHub Community

The votes and comments below were provided by the IdeaHub community prior to the idea's submission as a problem statement.

Idea Link: http://ideascale.com/t/UKsrZBi0l

Tags: Construction, Design, Sustainability

Votes:

Votes	
Up	2
Down	0
Total	**2**

Comments:

N/A