



TECH NOTE NO: 16
 TITLE: Concrete Mix Design Specification Evaluation
 AUTHOR: Z.C. Grasley, J.R. Roesler & D.A. Lange
 Ph: (217)721-5256, Email: rrodden@uiuc.edu
 CONTACT: University of Illinois, Dept of Civil & Environmental Engineering
 1211 NCEL, MC-250, Urbana, IL 61801
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1. Introduction

This technical note will summarize the mixture design specification guidelines from the FAA P-501 specification document. In addition, our view of each of the requirements and will be stated, along with a few suggested modifications. The two important issues that appear to be neglected by P-501 are shrinkage and fracture toughness/joint load transfer. Possible additions to the P-501 specifications will be proposed that account for these two issues.

2. Summary of P-501 Mix Design

The P-501 mixture design guidelines are summarized in Table 1 below. Our view of each statement is also listed. In general, most of the guidelines seem appropriate. However, the minimum cement content appears to be higher than what is necessary to meet the minimum strength requirements. Since there is already a minimum flexural strength requirement, this conservative approach to forcing 500 lb/yd³ cement content to meet strength is not justified.

Table 1. Summary of P-501 mix design and our view of each statement

P-501 Guidelines	Our View
max w/cm = 0.50	Ok
Min cement content = 500 lb/yd ³	This could be lower
min flexural strength = 600 psi @ 28 d	700 ok, could be 90 d
fly ash content range = 10-20%	Ok
fly ash + slag range = 25-55%	Ok
max slag when temp < 55 F = 30%	Ok
air content = 5.5% for 1.5" topline CA	Ok
air content = 6.0% for 0.75" topline CA	Ok

3. Suggested Additions to Specifications

The P-501 specification guidelines appear to focus primarily on ensuring that minimum strength requirements are obtained. Meeting the necessary strength is certainly critical, but additional specifications are needed if limiting shrinkage and ensuring good fracture toughness and joint load transfer (if dowels are not utilized) are of interest.

3.1 Shrinkage

Shrinkage of concrete (both drying and autogenous) is caused by the removal of water from capillary pores. In general, cement paste shrinks and aggregate does not. The simplest methods for reducing shrinkage include:

- Low paste content
- Moderate w/cm (to limit both drying and autogenous)
- Larger coarse aggregate (CA) topsize

Since aggregate do not shrink, lowering the paste content simply dilutes the shrinking volume. Low w/cm leads to high autogenous shrinkage, while high w/cm leads to high drying shrinkage. The optimum w/cm appears to be moderate level. Having a larger CA topsize appears to reduce shrinkage in a couple of ways: first, it allows for use of a lower paste content at the same slump. Second, the larger aggregates provide more restraint for the shrinking paste.

There are a couple of ways that shrinkage could be limited in the specifications:

- Measured shrinkage specification using ASTM standard
- Maximum strength specification
- Maximum cementitious materials content and min w/cm

There are also some limitations to the methods described above. Specifying a measured shrinkage specification using the ASTM C 157 standard does not account for any autogenous shrinkage, which is an artifact of the ASTM procedure. Autogenous shrinkage is primarily an early-age phenomenon, and the ASTM procedure requires wet curing for 28 days. One could meet the specification and still have high early shrinkage. The limitation to the maximum strength specification is that the specification could be achieved simply by using a low quality aggregate rather than by reducing paste content or increasing w/cm. One could meet the specification and still have a high shrinkage material.

We recommend considering specifying a maximum cementitious materials content and a minimum w/cm. This specification language does not suffer from the limitations described above for the first two possible specifications for limiting shrinkage. A possible value for the minimum w/cm is ~0.39-0.40. This value is low enough to permit the minimum strength requirements to be easily obtained, yet is high enough to limit severe autogenous shrinkage. We suggest that the

maximum cementitious materials content be determined by using mixtures used at other airport projects as precedent.

3.2 Fracture properties and joint load transfer

The easiest way to promote high fracture surface roughness and joint load transfer is to increase the fracture toughness. This increases the energy required to promote crack growth and encourages aggregate interlock at joints. Increasing the aggregate top size increases the fracture surface roughness. This is especially necessary if dowels were not going to be at every dummy contraction joint. We suggest that a coarse aggregate (CA) grading with CA top size of 1.5" be considered. Additional benefits of using a larger top size CA include reduced paste content for the same slump, which results in lower shrinkage and better economy.

4. Summary

The FAA P-501 guidelines for mixture design specifications are focused on ensuring that the necessary minimum strength is obtained. Suggested additions to the specifications that account for shrinkage and fracture toughness/joint load transfer have been suggested. The suggested additions include a specification for maximum cementitious materials content, minimum w/cm, and a CA top size of 1.5".