

# Double-bounded compressive strength pay factors for determining payment of in-place concrete



James Sullivan, David C. Novak, and Eric Hernandez  
Transportation Research Center, Grossman School of Business,  
College of Engineering and Mathematical Sciences at UVM



## Introduction

Under a double-bounded pay-factor system, in-place concrete whose compressive strength is exceedingly higher or lower than a target mean is paid at a lower rate than material closer to the target mean. The application of “pay factors” determines the amount of reward or penalty that is applied based on the lot average of 28-day concrete compressive strengths (CCS). These pay factors can vary around the target mean.

Designing a system of pay factors assumes that these incentives and disincentives exert pressure on an existing distribution of CCS in order to bring about a new shape to the distribution. This dynamic process is illustrated in Figure 1. The approach assumes that we have a current, or initial, distribution of industry-wide CCS that we want to change, a desired target distribution, and a system of pay incentives intended to exert pressure on the existing distribution.

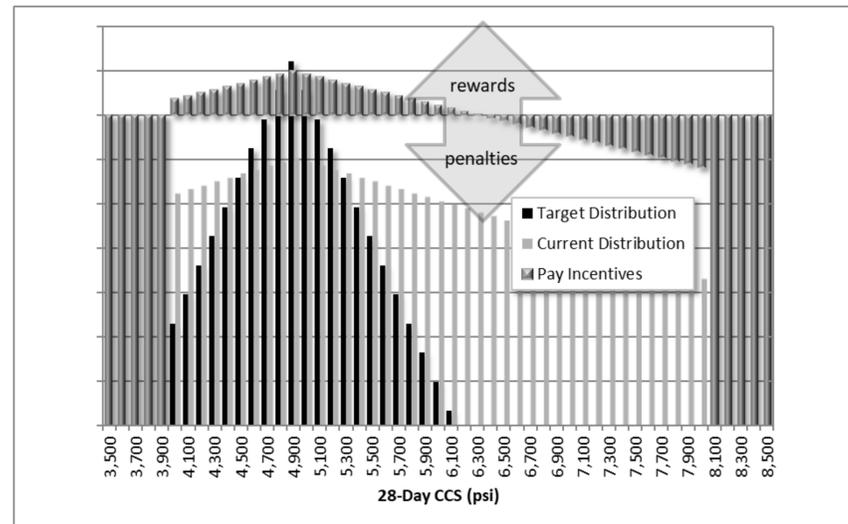


Figure 1. Pay Incentives (Rewards and Penalties) are used to exert pressure on a Current Distribution to shift it to a Target Distribution

The system of pay incentives rewards lots that fall closer to the peak of the target distribution, and penalizes lots that fall outside the more desirable range.

## Problem to be Solved

In the example given in Figure 1, the target distribution is Normal, but the current distribution is best approximated as a non-Normal function. Existing guidance for the use of a double-bounded pay factor system for the placement of concrete is inadequate if the target distribution and/or the industry response is non-Normal. The existing guidance also assumes that the incentives and disincentives are symmetrical around the target mean of the design distribution. However, this may also not be the case.

## Tasks

The following tasks will be undertaken for this project:

1. Develop a new approach for calculating payment from a distribution of 28-day CCS that is non-Normal
2. Demonstrate the implementation of the new approach for 3 5-year forecast scenarios

This project is expected to begin in October of 2020.

## New Methodological Approach

The first task will consist of the research team developing a new approach for calculating percent within limits (PWLs) from a 28-day CCS lot distribution that is non-Normal. Under the influence of a double-bounded pay factor system, the industry response is likely to be non-Normal, particularly when the peak of the target distribution is not central to the acceptable region, as shown in Figure 2.

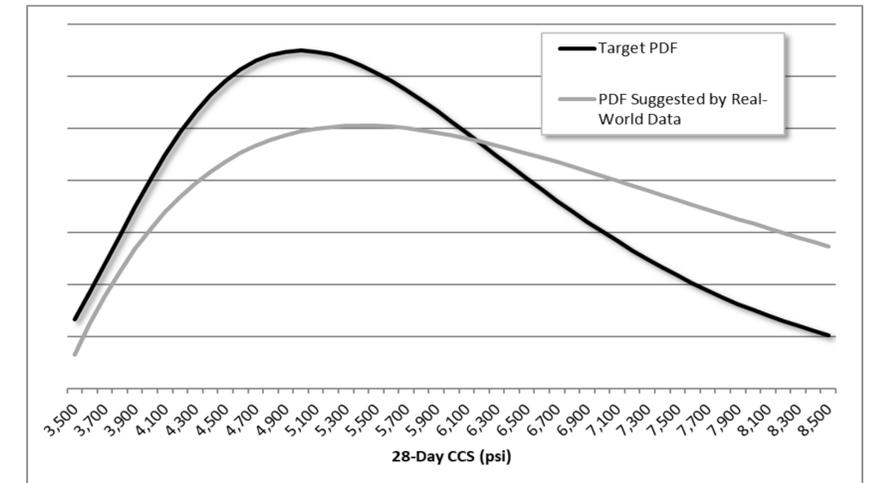


Figure 2. Conceptual Illustration of the new PWL Approach

The responses that the industry will take will be assumed probability distribution functions (PDFs). The new approach will consider a target PDF, in Figure 2 for example, upon which the pay incentives are based, and the response PDF suggested by samples taken from an in-place lot. The new approach will find a non-Normal PWL represented by the fraction of the PDF suggested by real-world data that falls within the target PDF.

## Industry Response Simulations

For the second task, the research team will simulate industry responses for a 5-year period beginning with the implementation of the double-bounded pay factors system. The team will use random variables (RVs) to represent industry-wide 28-day CCSs that result from the application of pay factors. Simulated industry responses will include a variety of assumed response “patterns”, or reactions to the pay factors. These patterns will be:

1. No response – no shift in the distribution of 28-day CCS is observed
2. Partial response – partial shift in the peak and/or the variance of the distribution of 28-day CCS is observed toward the target distribution
3. Dramatic response – complete shift in both the peak and variance of the distribution of 28-day CCS is observed, adhering to the target distribution

The results of each scenario will be a set of pay factors that balance Agency and industry risk.

## Acknowledgments

The authors would like to acknowledge the Transportation Infrastructure Durability Center (TIDC) at the University of Maine for providing funding for this work, and thank the project’s champion, Nicholas Van Den Berg, Materials & Certification Manager for the VTrans Materials & Certification Section