# Reduced Ball Roll Test Method

## Introduction

Ball roll control is an important property of synthetic turf designed for soccer. Soccer players want the roll of the soccer ball to be similar on synthetic and natural turf. The ball roll is also one of the first properties affected by wear or lack of maintenance on a synthetic turf field.

Laboratory testing of synthetic turf for ball roll is challenging due to the large sample size required for a full ball roll test. A ball roll test utilizing a smaller turf sample would be advantageous. Having a ball roll test that can be conducted on sample that has undergone simulated aging in a laboratory (such as the Lisport XL device) is also of great value for comparing the tendency of different synthetic turf systems to lose ball roll resistance with aging.

Several attempts to introduce a soccer ball roll test with a smaller sample size have been made (1,2). In 2015, FIFA introduced a reduced ball roll test to be used in the laboratory testing of turf products for soccer (3). The details of the mechanics of the test are explained well in the FIFA Test Method Manual, but some of the methodology for the data analysis may not be clear to the average user. This white paper gives a step-by-step explanation of how to use the data collected in the reduced ball roll test to estimate a full ball roll for the synthetic turf system.

## Summary of the Test Method

The test method measures the change in the soccer ball velocity caused by the ball rolling across a 1.5 meter sample of turf. Using four different starting velocities, a mathematical equation describing this velocity change can be derived for that turf sample. Through an iterative process described below, a prediction is made for how far the ball would roll on full ball roll test.

## Test Method

### Measuring Velocities

The ball is rolled down the 45$^o$ angle ramp and allowed to stabilize across the Initial Distance ($S_i$). The soccer ball then rolls through two electronic timing gates that are used to measure the velocity of the soccer ball at two locations on the sample (Figure 1). The distance between the centers of the two electronic timing gates is the Roll Distance (S). FIFA Test Method 17 utilizes 1.0 meter for the Initial Distance and 1.5 meter for the Roll Distance.

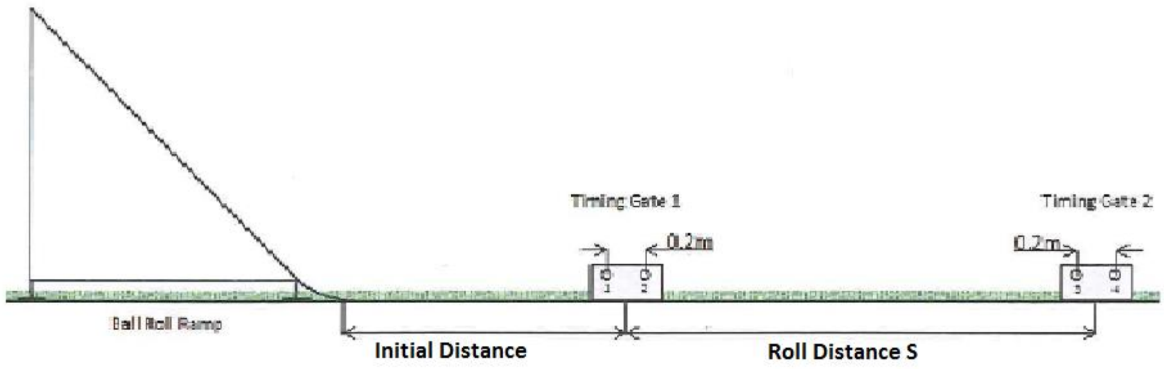



Figure 1. Reduced Ball Roll Apparatus

The timing lights on each gate are 0.2 meters apart. The ball traveling through Timing Gate 1 triggers a timer when it passes the first light switch which starts the timing clock running. The timing clock stops when the ball passes the second light switch on Timing Gate 1. Knowing the time and the distance between the two light switches, the velocity of the ball within that Timing Gate 1 ( $V_{initial}$) is calculated using Equation 1.

V = distance between lights/time (Equation 1)

The final velocity ($V_{final}$) is measured in the same manner at Timing Gate 2.

**Roll Heights**

The roll height of the ball is measured from 4 positions on the ramp (Figure 2). The different release heights will produce different velocities for the ball when it reaches the surface. The highest position should be the standard height for the full ball roll (1 meter). The lowest height must assure that the ball continues to roll through Timing Gate 2. Two intermediate heights are chosen between the highest and lowest heights. FIFA Test Method 17 specifies that the roll is repeated three times at the lower two heights and the roll is repeated two times at the higher two heights. The averages of the rolls at each height are then calculated.

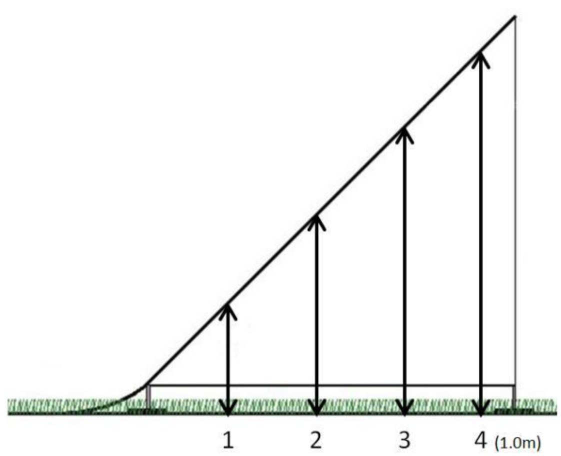



Figure 2. Different Ball Release Heights

Using different initial velocities, a relationship between the Initial Velocity and the Final Velocity (which is controlled by the ball/surface interaction) can be described as a second order polynomial function (Equation 2).

$$V_{Final} = a( V_{Initial})^2 + b(V_{Initial}) + c \quad \text{(Equation 2)}$$

An example of how this equation can be calculated in Excel is shown as the Example Calculation in the Appendix. In the example, the average V(initial) and V(final) values for each release height are placed in the data table at the top of the spreadsheet. The eight cells containing the average initial and final velocities are selected. From the Insert Tab, select Chart and Scatter Chart. A scatter chart with $V_{(initial)}$ as the X axis and $V_{(final)}$ as the Y axis will appear. After the chart appears, select Add Chart Element from the Charts Layout Tab. From the Add Chart Element menu, select Trend Line and then select More Trend Line Options. Chose Polynomial as the trend line format and set the polynomial order to 2. Scroll down and select the box for Display Equation on Chart. You can also select Display R squared value on chart to see how well the curve fits the data.

The y and x variables in the polynomial equation represent V(Final) and V(Initial) variables in Equation 2. The constants a, b, and c are then substituted into Equation 2 to give the relationship between initial and final velocities for this turf system.

**Predicted Ball Roll Calculation**

The total predicted ball roll from the reduced ball roll procedure is calculated using the three values in Equation 3.

$$\text{Predicted Ball Roll} = S_i + S_p + S_r \quad \text{(Equation 3)}$$

Where Si is the initial distance from the end of the ramp to the first timing gate (1 meter), Sp is the primary part of the ball roll, and Sr is the residual ball roll. We will not discuss the calculation of the primary and residual ball roll.

**Primary Ball Roll**

The primary ball roll is calculated using an iterative process. The iterative process will be described using the table on the bottom of the spread sheet in the Appendix. In the bottom table, the $V_I$ for Iteration 1 is the experimentally determined initial average velocity for the 1 meter roll height. In the cell under $V_F$ input the polynomial equation referencing the value of the cell containing $V_I$ (for this example the input is "=-0.589*ACC^2+4.62*ACC-6.15" where ACC is the cell number for $V_I$). The calculated $V_F$ for the first iteration becomes the initial velocity for the second iteration. Continue doing iterations until the $V_F$ becomes negative. The primary ball roll portion ($S_p$)of the total ball roll distance is calculated using Equation 4.

$S_p$ = S (distance between gates) X number of iterations (Equation 4)

The number of iterations before $V_F$ becomes negative in our example is 3, so for this example $S_p$ is equal to 3 X 1.5 or 4.5 meters.

**Residual Ball Roll**

The final portion of the ball roll calculation is the distance traveled during the last iteration (where $V_F$ is negative) before coming to a complete stop. A kinematic equation for a system with constant acceleration is shown as Equation 5.

$$V_F^2 = V_I^2 + 2as \quad \text{(Equation 5)}$$

Where $V_F$ and $V_I$ are the initial and final velocities, a is the acceleration, and s is the distance traveled. Equation 5 can be arranged to calculate either acceleration or distance. Equation 5 can be rearranged to Equation 6 to calculate the acceleration (actually deceleration) during the next to last iteration process where the distance, s, is 1.5 meters.

$$a = (V_F^2 - V_I^2)/2s \quad \text{(Equation 6)}$$

Substituting the values for $V_F$ and $V_I$ from the next to last iteration and the distance of 1.5 meters into Equation 6 the acceleration is -1.07 m/sec$^2$.

If the acceleration is known, Equation 5 can be rearranged into Equation 7 to calculate a distance.

$$s= ((V_F^2 - V_I^2)/2a \quad \text{(Equation 7)}$$

For the residual ball roll $S_r$, the final velocity is zero (ball rolls to a stop), so Equation 7 becomes Equation 8 where we can

$$S_r = -V_I^2/2a \quad \text{(Equation 8)}$$

substitute the initial velocity for the final iteration and the deceleration value to calculate the residual distance. In the case of the example, the residual distance is 0.08 meters.

So, from Equation 3, substituting known value of $S_i$, with the calculated values for $S_p$ and $S_r$ we get the predicted ball roll.

$$\text{Predicted Ball Roll} = S_i + S_p + S_r$$
$$= 1.0 + 4.5 + 0.08 \text{ or } 5.58 \text{ meters}$$

**References**

1. H. J. Kolitzus, (2003). Ball Roll Behavior, International Association for Sports Surface Sciences Publication

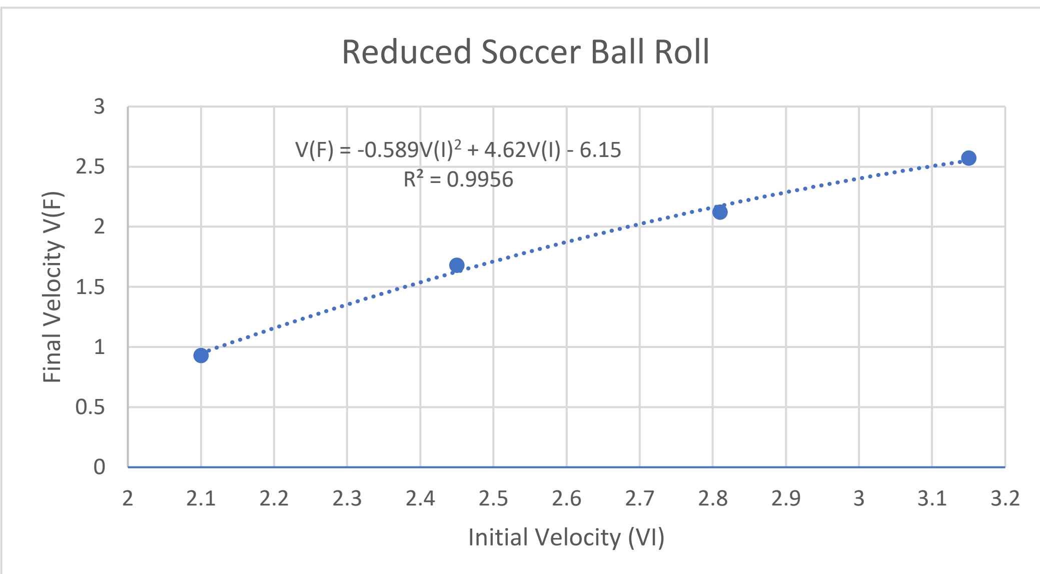
2. M. Gabrielsen, (2004). Ball Roll, International Association for Sports Surface Sciences Publication
3. FIFA, 2015, FIFA Quality Program for Football Turf, Manual of Test Methods, Method 22

Appendix: Example Excel Spreadsheet

**Example of Reduced Soccer Ball Roll on Turf**

**Derivation of Polynomial Equation**

| Release Height | V Initial | V Final |
|---|---|---|
| 0.25 M | 2.1 | 0.93 |
| 0.50 M | 2.45 | 1.68 |
| 0.75 M | 2.81 | 2.12 |
| 1.0 M | 3.15 | 2.57 |




$V_F = -0.589\ V_I^2 + 4.62V_I - 6.15$

| Iteration | $V_I$ | $V_F$ |
|---|---|---|
| 1 | 3.15 | 2.56 |
| 2 | 2.56 | 1.81 |
| 3 | 1.81 | 0.29 |
| 4 | 0.29 | -4.84 |