BYGGFORSK
Norwegian Building Research Institute

Head Office
Forskningsveien 3b
P.O.Box 123 Blindern
NO-0314 OSLO
Tel. +47 22 96 55 55
Fax +47 22 69 94 38

Local Department
Høgskoleringen 7b
NO-7491 TRONDHEIM
Tel. +47 73 59 33 90
Fax +47 73 59 33 80

E-mail firmapost@byggforsk.no
Internet www.byggforsk.no
Registration No. NO 943 813 361 VAT

Client
UEFA
Client's address Route de Genève CH – 1260 Nyon
Client's contact-person Rolf Hediger

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Project leader Sign.	Responsible manager Sign.	Quality assurance Sign.
Morten Gabrielsen	Sigurd Hveem	Jørund Furre

Assignment Report

Connection between ball roll distance and velocity change

Summary

The Norwegian Building Research Institute (NBI) was asked by UEFA to fulfil a test program and if possible find a way to calculate the Ball Roll Distance (BRD) based on the Velocity Change (VC) over a two meters interval. These results are based on a total of 360 measurements of BRD and VC, including the tests reported to UEFA in August 2003.

The tests have been carried out on five 3rd generation artificial grass fields (outdoor), three natural grass fields (outdoor) and one artificial grass in laboratory with three different fill heights.

The results shows that though the correlation between BRD and VC varies within a series of ten drops, the average values of ten drops can be used to calculate the Ball Roll Distance based on the Velocity Change.

This correlation can be expressed mathematically by the formula:

$$BRD = 4{,}3404\ VC^{-0{,}9789}$$

Address of the building			Built (year)
	Method UEFA	Keywords	Filename Ball roll

1. Introduction

The Norwegian Building Research Institute (NBI) has been asked by UEFA to fulfil a test program for Ball Roll, and if possible, try to find a way to estimate the Ball Roll Distance (BRD) based on the Velocity Change (VC) over a two meters interval. The background for the project is that NBI did some unofficial tests and informed UEFA that it possible was a correlation between BRD and the VC. UEFA became interested and asked NBI to check it out more systematically.

2. Test Program

The tests are done in accordance with the description given in the UEFA manual of May 2003: The ball is dropped from the ball roll ramp at a given height and rolls between two timing gates. The Velocity Change (VC) between the timing gates can then be calculated and compared with the measured Ball Roll Distance (BRD).

Inclusive the results reported in August 2003, this program contains the following test objects:

- Six 3rd generation artificial grass constructions in field, outdoor.
- Three natural grass fields, outdoor
- One type of 3rd generation artificial grass with three different fill heights, measured in laboratory

For the outdoor installations tested after August 2003, the BRD and VC was measured in four directions, two longitudinal in opposite directions at the centre of the field, and two transversal opposite directions with and against the sloop. The fields tested in August, and the laboratory tests, were carried out in two opposite directions, longitudinal. For each direction the ball was dropped 10 times.

Input values

Drop height: 1 m
Distance between timing gates: 2 m
Distance between ball ramp and timing gate: 0,5 m

Measured values

Ball Roll Distance	BRD [m]
Time to pass the first timing gate	t_1 [s^{-4}]
Time to pass the second timing gate	t_2 [s^{-4}]

Calculated values

Velocity at first timing gate:	v_1 [m/s]
Velocity at second timing gate:	v_2 [m/s]
Velocity Change, $VC = V_1 - V_2$	VC [m/s]

The artificial fields tested are:
- Soccergrass TD 50 with pad (Rolvsrud). Installed June 2003
- Monoslide 2050 (Grei). Installed Mai 2003
- Saltex PE 6010 tested August 2003 (Idrettshøyskolen). Installed August 2003
- Saltex PE 6010 tested October 2003 (Idrettshøyskolen). Installed August 2003
- Desso, before brushing (Vallhall). Installed 2000
- Desso, after brushing (Vallhall). Installed 2000

The fields with natural grass are:
- Nadderud (top division club)
- Ullevål (national arena)
- Åråsen. (top division club)

Laboratory tests:
Saltex PE 6008 with free pile heights of 25 mm.
Saltex PE 6008 with free pile heights of 20 mm.
Saltex PE 6008 with free pile heights of 15 mm.

3. Results

The following tables show the measured and calculated average values for VC and BRD for the artificial grass fields, the natural grass fields and the laboratory tests.

Table 1 shows the average BRD vs VC values for all the different fields and directions

Field	BRD	VC
Rolvsrud, longitudional	14,50	0,30
Rolvsrud, transversal	14,80	0,31
Grei, longitudional	11,70	0,33
Vallhall-1	12,60	0,35
Vallhall-2	10,40	0,42
Grei, transversal	13,60	0,33
Lab - 15	8,10	0,48
Idrettshøgskolen, -1-b	7,00	0,50
Idrettshøgskolen, longitudional	9,90	0,57
Nadderud, transversal (natural)	6,60	0,57
Lab - 20	6,90	0,61
Ullevål, longitudional (natural)	6,60	0,62
Lab - 25	6,20	0,64
Årråsen, transversal (natural)	6,00	0,65
Idrettshøgskolen, transversal	8,50	0,68
Ullevål, transversal (natural)	5,80	0,68
Nadderud , longitudional (natural)	5,80	0,73
Idrettshøgskolen-1.	5,80	0,77
Åråsen , longitudional (natural)	5,50	0,82

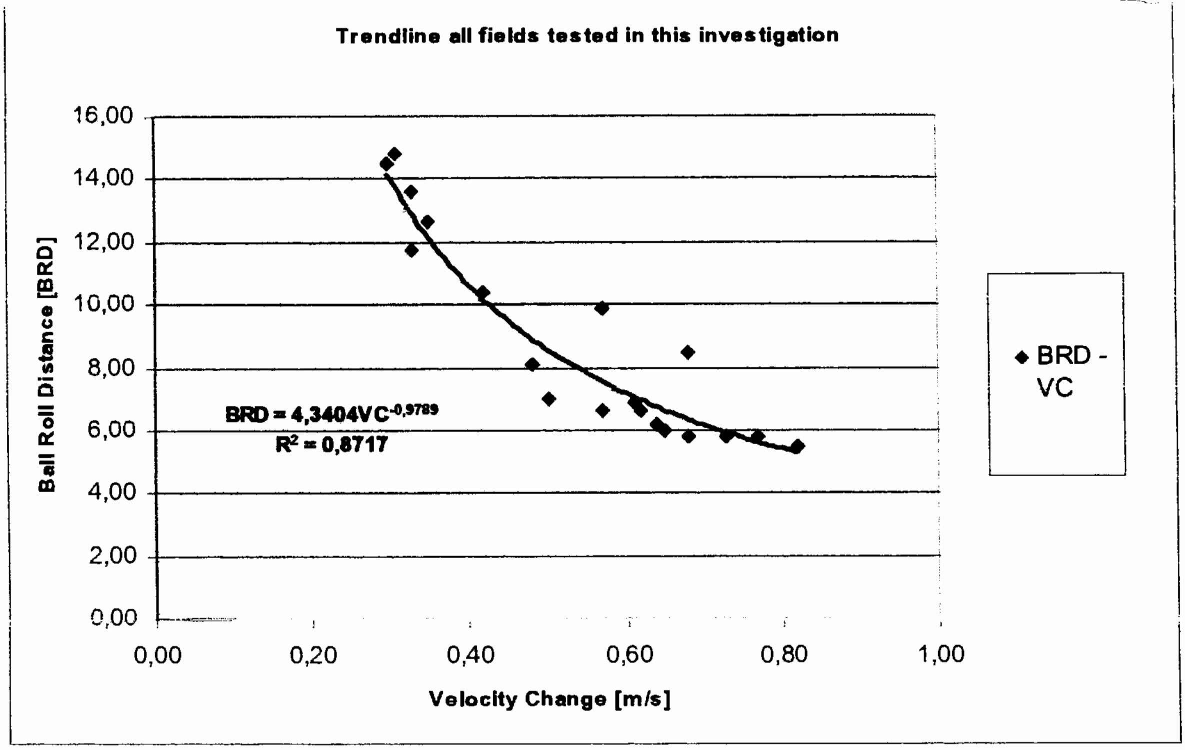


Diagram 1 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for all the fields and directions tested in this investigation.

Table 2 shows the correlation between VC and BRD based on the formula in diagram 1.

VC	BRD
0,15	27,8
0,20	21,0
0,25	16,9
0,30	14,1
0,35	12,1
0,40	10,6
0,45	9,5
0,50	8,6
0,55	7,8
0,60	7,2
0,65	6,6
0,70	6,2
0,75	5,8
0,80	5,4
0,85	5,1

4. Conclusion

The results shows that though the correlation between BRD and VC varies within a series of ten drops, the average values of ten drops can be used to calculate the Ball Roll Distance based on the Velocity Change.

This correlation can be expressed mathematically by the formula:

$$BRD = 4{,}3404\ VC^{-0{,}9789}$$

Oslo, 18.12.2003
Norwegian Building Research Institute

Morten Gabrielsen

Jøgund Furre

APPENDIX 1, RESULTS FROM THE DIFFERENT OBJECTS

Artificial grass in field. (The results from August is not included)

Table 1. Rolvsrud longitidional (Soccergrass TD 50 with pad)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	637	720	14,2	3,14	2,78	**0,36**
2	654	725	14,5	3,06	2,76	**0,30**
3	645	711	14,9	3,10	2,81	**0,29**
4	641	713	15,1	3,12	2,81	**0,32**
5	635	715	14,8	3,15	2,80	**0,35**
6	645	710	15,3	3,10	2,82	**0,28**
7	643	720	14,2	3,11	2,78	**0,33**
8	652	733	14,9	3,07	2,73	**0,34**
9	657	722	15,1	3,04	2,77	**0,27**
10	642	711	14,8	3,12	2,81	**0,30**
Average	**645**	**718**	**14,8**	**3,10**	**2,79**	**0,31**

Table 2. Rolvsrud longitidional (Soccergrass TD 50 with pad)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	649	726	**14,0**	3,08	2,75	**0,33**
2	651	713	**15,1**	3,07	2,81	**0,27**
3	644	710	**14,3**	3,11	2,82	**0,29**
4	652	721	**13,6**	3,07	2,77	**0,29**
5	651	722	**12,7**	3,07	2,77	**0,30**
6	645	720	**15,2**	3,10	2,78	**0,32**
7	640	698	**15,6**	3,13	2,87	**0,26**
8	644	720	**14,7**	3,11	2,78	**0,33**
9	645	718	**14,0**	3,10	2,79	**0,32**
10	641	703	**15,7**	3,12	2,84	**0,28**
Average	**646**	**715**	**14,5**	**3,10**	**2,80**	**0,30**

Table 3. Rolvsrud transversal against the slope (Soccergrass TD 50 with pad)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	653	736	**12,1**	3,06	2,72	**0,35**
2	639	718	**12,5**	3,13	2,79	**0,34**
3	648	715	**13,1**	3,09	2,80	**0,29**
4	639	723	**12,4**	3,13	2,77	**0,36**
5	642	714	**12,8**	3,12	2,80	**0,31**
6	634	719	**13,1**	3,15	2,78	**0,37**
7	628	691	**13,9**	3,18	2,89	**0,29**
8	629	704	**13,5**	3,18	2,84	**0,34**
9	634	700	**13,6**	3,15	2,86	**0,30**
10	644	725	**12,6**	3,11	2,76	**0,35**
Average	**639**	**715**	**12,9**	**3,13**	**2,80**	**0,33**

Table 4. Rolvsrud transversal with the slope (Soccergrass TD 50 with pad)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	639	705	**17,5**	3,13	2,84	**0,29**
2	642	718	**17,3**	3,12	2,79	**0,33**
3	631	639	**18,3**	3,17	3,13	**0,04**
4	629	699	**18,1**	3,18	2,86	**0,32**
5	640	705	**16,6**	3,13	2,84	**0,29**
6	641	699	**16,0**	3,12	2,86	**0,26**
7	653	720	**15,6**	3,06	2,78	**0,29**
8	639	720	**15,7**	3,13	2,78	**0,35**
9	644	715	**16,4**	3,11	2,80	**0,31**
10	633	712	**15,9**	3,16	2,81	**0,35**
Average	**639**	**703**	**16,7**	**3,13**	**2,85**	**0,28**

Table 5. Grei longitudional (Monoslide 2050)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	637	732	**12,2**	3,14	2,73	**0,41**
2	621	684	**13,2**	3,22	2,92	**0,30**
3	645	722	**12,3**	3,10	2,77	**0,33**
4	661	734	**13,1**	3,03	2,72	**0,30**
5	647	735	**13,0**	3,09	2,72	**0,37**
6	689	754	**12,4**	2,90	2,65	**0,25**
7	709	792	**11,4**	2,82	2,53	**0,30**
8	736	827	**11,4**	2,72	2,42	**0,30**
9	739	816	**11,7**	2,71	2,45	**0,26**
10	703	776	**12,2**	2,84	2,58	**0,27**
Average	**679**	**757**	**12,3**	**2,96**	**2,65**	**0,31**

Table 6. Grei longitudional (Monoslide 2050)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	669	765	**10,2**	2,99	2,61	**0,38**
2	655	735	**11,7**	3,05	2,72	**0,33**
3	653	752	**10,4**	3,06	2,66	**0,40**
4	641	716	**11,5**	3,12	2,79	**0,33**
5	648	713	**11,6**	3,09	2,81	**0,28**
6	661	756	**11,0**	3,03	2,65	**0,38**
7	645	728	**11,6**	3,10	2,75	**0,35**
8	643	715	**11,1**	3,11	2,80	**0,31**
9	640	720	**11,6**	3,13	2,78	**0,35**
10	646	733	**10,7**	3,10	2,73	**0,37**
Average	**650**	**733**	**11,1**	**3,08**	**2,73**	**0,35**

Table 7. Grei transversal with the slope (Monoslide 2050)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	633	686	**17,3**	3,16	2,92	**0,24**
2	638	698	**17,4**	3,13	2,87	**0,27**
3	632	674	**18,3**	3,16	2,97	**0,20**
4	642	715	**15,5**	3,12	2,80	**0,32**
5	616	650	**20,7**	3,25	3,08	**0,17**
6	613	661	**17,3**	3,26	3,03	**0,24**
7	631	704	**15,5**	3,17	2,84	**0,33**
8	620	687	**16,2**	3,23	2,91	**0,31**
9	635	711	**15,1**	3,15	2,81	**0,34**
10	641	686	**17,5**	3,12	2,92	**0,20**
Average	**630**	**687**	**17,1**	**3,17**	**2,91**	**0,26**

Table 8. Grei transversal against the slope (Monoslide 2050)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	660	767	**10,2**	3,03	2,61	**0,42**
2	657	770	**9,9**	3,04	2,60	**0,45**
3	647	729	**11,1**	3,09	2,74	**0,35**
4	651	748	**9,7**	3,07	2,67	**0,40**
5	639	728	**10,3**	3,13	2,75	**0,38**
6	648	743	**10,1**	3,09	2,69	**0,39**
7	657	755	**9,4**	3,04	2,65	**0,40**
8	642	741	**9,4**	3,12	2,70	**0,42**
9	639	737	**10,9**	3,13	2,71	**0,42**
10	651	755	**10,4**	3,07	2,65	**0,42**
Average	**649**	**747**	**10,1**	**3,08**	**2,68**	**0,40**

Table 9. Idrettshøgskolen longitudional (Saltex PE 6010)

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	686	810	**10,4**	2,92	2,47	**0,45**
2	699	824	**10,3**	2,86	2,43	**0,43**
3	714	838	**10,0**	2,80	2,39	**0,41**
4	725	850	**9,9**	2,76	2,35	**0,41**
5	741	922	**8,7**	2,70	2,17	**0,53**
6	759	872	**10,1**	2,64	2,29	**0,34**
7	742	906	**9,3**	2,70	2,21	**0,49**
8	738	903	**9,1**	2,71	2,21	**0,50**
9	742	942	**8,9**	2,70	2,12	**0,57**
10	764	902	**9,2**	2,62	2,22	**0,40**
Average	**731**	**877**	**9,6**	**2,74**	**2,29**	**0,45**

Table 10. Idrettshøgskolen longitudinal (Saltex PE 6010)

Measuring nr.	*t_1 [1^{-4} s]*	*t_2 [1^{-4} s]*	*BRD [m]*	*v_1 [m/s]*	*v_2 [m/s]*	Δv [m/s]
1	655	857	**10,0**	3,05	2,33	**0,72**
2	643	844	**10,6**	3,11	2,37	**0,74**
3	649	898	**9,9**	3,08	2,23	**0,85**
4	710	854	**10,4**	2,82	2,34	**0,47**
5	655	906	**9,9**	3,05	2,21	**0,85**
6	727	896	**10,2**	2,75	2,23	**0,52**
7	663	870	**10,0**	3,02	2,30	**0,72**
8	657	896	**10,2**	3,04	2,23	**0,81**
9	671	959	**9,4**	2,98	2,09	**0,90**
10	747	865	**10,2**	2,68	2,31	**0,37**
Average	**678**	**885**	**10,1**	**2,96**	**2,26**	**0,69**

Table 11. Idrettshøgskolen transversal with the slope (Saltex PE 6010)

Measuring nr.	*t_1 [1^{-4} s]*	*t_2 [1^{-4} s]*	*BRD [m]*	*v_1 [m/s]*	*v_2 [m/s]*	Δv [m/s]
1	720	938	**8,8**	2,78	2,13	**0,65**
2	694	966	**8,5**	2,88	2,07	**0,81**
3	745	913	**9,4**	2,68	2,19	**0,49**
4	630	878	**10,1**	3,17	2,28	**0,90**
5	673	932	**9,3**	2,97	2,15	**0,83**
6	715	912	**9,1**	2,80	2,19	**0,60**
7	669	934	**8,7**	2,99	2,14	**0,85**
8	682	896	**9,6**	2,93	2,23	**0,70**
9	712	901	**9,3**	2,81	2,22	**0,59**
10	705	876	**10,1**	2,84	2,28	**0,55**
Average	**695**	**915**	**9,3**	**2,89**	**2,19**	**0,70**

Table 12. Idrettshøgskolen transversal against the slope (Saltex PE 6010)

Measuring nr.	*t_1 [1^{-4} s]*	*t_2 [1^{-4} s]*	*BRD [m]*	*v_1 [m/s]*	*v_2 [m/s]*	Δv [m/s]
1	716	937	7,5	2,79	2,13	**0,66**
2	727	960	7,7	2,75	2,08	**0,67**
3	742	904	7,5	2,70	2,21	**0,48**
4	731	971	7,8	2,74	2,06	**0,68**
5	747	915	7,9	2,68	2,19	**0,49**
6	686	943	7,4	2,92	2,12	**0,79**
7	699	979	7,1	2,86	2,04	**0,82**
8	708	930	7,7	2,82	2,15	**0,67**
9	708	903	8,0	2,82	2,21	**0,61**
10	728	946	7,6	2,75	2,11	**0,63**
Average	**719**	**939**	7,6	**2,78**	**2,13**	**0,65**

Natural grass:

Table 13. Nadderud longitudional

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	674	899	**5,7**	2,97	2,22	**0,74**
2	651	870	**5,8**	3,07	2,30	**0,77**
3	668	922	**5,3**	2,99	2,17	**0,82**
4	641	864	**5,5**	3,12	2,31	**0,81**
5	668	899	**5,5**	2,99	2,22	**0,77**
6	663	852	**6,1**	3,02	2,35	**0,67**
7	696	925	**5,5**	2,87	2,16	**0,71**
8	674	867	**6,2**	2,97	2,31	**0,66**
9	672	884	**5,6**	2,98	2,26	**0,71**
10	659	848	**6,0**	3,03	2,36	**0,68**
Average	**667**	**883**	**5,7**	**3,00**	**2,27**	**0,73**

Table 14. Nadderud longitudional

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	673	909	**5,4**	2,97	2,20	**0,77**
2	679	873	**6,0**	2,95	2,29	**0,65**
3	668	889	**5,5**	2,99	2,25	**0,74**
4	668	876	**5,7**	2,99	2,28	**0,71**
5	668	907	**5,6**	2,99	2,21	**0,79**
6	668	897	**5,6**	2,99	2,23	**0,76**
7	672	886	**5,8**	2,98	2,26	**0,72**
8	663	844	**6,1**	3,02	2,37	**0,65**
9	662	878	**6,0**	3,02	2,28	**0,74**
10	650	832	**6,5**	3,08	2,40	**0,67**
Average	**667**	**879**	**5,8**	**3,00**	**2,28**	**0,72**

Table 15. Nadderud transversal with slope

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	659	795	**6,9**	3,03	2,52	**0,52**
2	668	787	**7,0**	2,99	2,54	**0,45**
3	660	791	**6,7**	3,03	2,53	**0,50**
4	667	802	**7,1**	3,00	2,49	**0,50**
5	648	814	**6,5**	3,09	2,46	**0,63**
6	646	786	**7,0**	3,10	2,54	**0,55**
7	668	805	**6,4**	2,99	2,48	**0,51**
8	655	774	**7,4**	3,05	2,58	**0,47**
9	654	797	**6,7**	3,06	2,51	**0,55**
10	659	783	**7,1**	3,03	2,55	**0,48**
Average	**658**	**793**	**6,9**	**3,04**	**2,52**	**0,52**

Table 16. Nadderud transversal against slope

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	668	837	**6,1**	2,99	2,39	**0,60**
2	663	808	**6,5**	3,02	2,48	**0,54**
3	658	838	**6,0**	3,04	2,39	**0,65**
4	647	831	**6,6**	3,09	2,41	**0,68**
5	662	848	**5,4**	3,02	2,36	**0,66**
6	667	828	**6,3**	3,00	2,42	**0,58**
7	655	809	**6,4**	3,05	2,47	**0,58**
8	660	807	**6,7**	3,03	2,48	**0,55**
9	674	854	**6,0**	2,97	2,34	**0,63**
10	656	807	**6,5**	3,05	2,48	**0,57**
Average	**661**	**827**	**6,2**	**3,03**	**2,42**	**0,61**

Table 17. Ullevål longitudional

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	665	841	**6,4**	3,01	2,38	**0,63**
2	662	824	**6,6**	3,02	2,43	**0,59**
3	650	831	**6,0**	3,08	2,41	**0,67**
4	653	823	**6,2**	3,06	2,43	**0,63**
5	659	827	**6,2**	3,03	2,42	**0,62**
6	660	815	**6,6**	3,03	2,45	**0,58**
7	667	850	**6,0**	3,00	2,35	**0,65**
8	678	843	**6,2**	2,95	2,37	**0,58**
9	673	823	**6,8**	2,97	2,43	**0,54**
10	656	823	**6,4**	3,05	2,43	**0,62**
Average	**662**	**830**	**6,3**	**3,02**	**2,41**	**0,61**

Table 18. Ullevål longitudional

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	662	843	**6,7**	3,02	2,37	**0,65**
2	651	828	**6,8**	3,07	2,42	**0,66**
3	679	859	**6,6**	2,95	2,33	**0,62**
4	660	832	**7,0**	3,03	2,40	**0,63**
5	650	832	**6,9**	3,08	2,40	**0,67**
6	666	836	**7,1**	3,00	2,39	**0,61**
7	654	816	**7,3**	3,06	2,45	**0,61**
8	656	827	**7,2**	3,05	2,42	**0,63**
9	654	836	**6,6**	3,06	2,39	**0,67**
10	653	810	**7,2**	3,06	2,47	**0,59**
Average	**659**	**832**	**6,9**	**3,04**	**2,40**	**0,63**

Table 19. Ullevål transversal with slope

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	668	868	**5,8**	2,99	2,30	**0,69**
2	671	837	**6,2**	2,98	2,39	**0,59**
3	714	968	**5,4**	2,80	2,07	**0,74**
4	677	876	**5,6**	2,95	2,28	**0,67**
5	695	873	**6,1**	2,88	2,29	**0,59**
6	694	926	**5,9**	2,88	2,16	**0,72**
7	697	907	**5,6**	2,87	2,21	**0,66**
8	716	966	**5,4**	2,79	2,07	**0,72**
9	699	909	**5,8**	2,86	2,20	**0,66**
10	689	868	**6,0**	2,90	2,30	**0,60**
Average	**692**	**900**	**5,8**	**2,89**	**2,23**	**0,66**

Table 20. Ullevål transversal against slope

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	661	856	**5,9**	3,03	2,34	**0,69**
2	633	831	**6,4**	3,16	2,41	**0,75**
3	699	930	**5,6**	2,86	2,15	**0,71**
4	710	931	**5,7**	2,82	2,15	**0,67**
5	706	943	**5,6**	2,83	2,12	**0,71**
6	709	911	**5,8**	2,82	2,20	**0,63**
7	713	959	**5,6**	2,81	2,09	**0,72**
8	691	903	**6,1**	2,89	2,21	**0,68**
9	695	899	**5,6**	2,88	2,22	**0,65**
10	689	920	**5,2**	2,90	2,17	**0,73**
Average	**691**	**908**	**5,7**	**2,90**	**2,21**	**0,69**

Table 21. Åråsen longitudional

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	BRD [m]	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	645	821	**6,6**	3,10	2,44	**0,66**
2	627	850	**6,7**	3,19	2,35	**0,84**
3	656	913	**6,2**	3,05	2,19	**0,86**
4	659	895	**6,1**	3,03	2,23	**0,80**
5	667	920	**6,3**	3,00	2,17	**0,82**
6	654	918	**6,3**	3,06	2,18	**0,88**
7	665	883	**6,5**	3,01	2,27	**0,74**
8	709	875	**6,6**	2,82	2,29	**0,54**
9	698	910	**6,4**	2,87	2,20	**0,67**
10	648	862	**6,7**	3,09	2,32	**0,77**
Average	**663**	**885**	**6,4**	**3,02**	**2,26**	**0,76**

Table 22. Åråsen longitudional

Measuring nr.	t_1 *[1^-4 s]*	t_2 *[1^-4 s]*	*BRD [m]*	v_1 *[m/s]*	v_2 *[m/s]*	Δv [m/s]
1	727	1112	**4,6**	2,75	1,80	**0,95**
2	714	1010	**4,8**	2,80	1,98	**0,82**
3	720	1008	**5,0**	2,78	1,98	**0,79**
4	744	1047	**4,9**	2,69	1,91	**0,78**
5	762	1179	**4,5**	2,62	1,70	**0,93**
6	766	1182	**4,4**	2,61	1,69	**0,92**
7	762	1161	**4,6**	2,62	1,72	**0,90**
8	748	1133	**4,7**	2,67	1,77	**0,91**
9	780	1196	**4,5**	2,56	1,67	**0,89**
10	769	1139	**4,7**	2,60	1,76	**0,84**
Average	**749**	**1117**	**4,6**	**2,67**	**1,80**	**0,87**

Table 23. Åråsen transversal with slope

Measuring nr.	t_1 *[1^-4 s]*	t_2 *[1^-4 s]*	*BRD [m]*	v_1 *[m/s]*	v_2 *[m/s]*	Δv [m/s]
1	684	850	**6,7**	2,92	2,35	**0,57**
2	687	869	**6,8**	2,91	2,30	**0,61**
3	711	903	**6,6**	2,81	2,21	**0,60**
4	739	911	**6,2**	2,71	2,20	**0,51**
5	691	862	**7,0**	2,89	2,32	**0,57**
6	726	886	**6,5**	2,75	2,26	**0,50**
7	702	856	**6,8**	2,85	2,34	**0,51**
8	727	901	**6,3**	2,75	2,22	**0,53**
9	673	812	**7,4**	2,97	2,46	**0,51**
Average	**704**	**872**	**6,7**	**2,84**	**2,30**	**0,55**

Table 24. Åråsen transversal against slope

Measuring nr.	t_1 *[1^-4 s]*	t_2 *[1^-4 s]*	*BRD [m]*	v_1 *[m/s]*	v_2 *[m/s]*	Δv [m/s]
1	692	957	**5,1**	2,89	2,09	**0,80**
2	698	972	**5,2**	2,87	2,06	**0,81**
3	709	964	**5,3**	2,82	2,07	**0,75**
4	700	942	**5,4**	2,86	2,12	**0,73**
5	696	1028	**4,9**	2,87	1,95	**0,93**
6	694	1027	**4,9**	2,88	1,95	**0,93**
7	720	967	**5,5**	2,78	2,07	**0,71**
8	728	980	**5,3**	2,75	2,04	**0,71**
9	713	1021	**5,0**	2,81	1,96	**0,85**
10	716	962	**5,3**	2,79	2,08	**0,71**
Average	**707**	**982**	**5,2**	**2,83**	**2,04**	**0,79**

Laboratory tests:

Table 25. Saltex 6008. Fillheight 35 mm

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	668	859	**5,8**	2,99	2,33	**0,67**
2	648	811	**6,2**	3,09	2,47	**0,62**
3	641	825	**5,9**	3,12	2,42	**0,70**
4	663	822	**6,2**	3,02	2,43	**0,58**
5	646	812	**6,3**	3,10	2,46	**0,63**
6	672	838	**6,1**	2,98	2,39	**0,59**
7	670	842	**6,2**	2,99	2,38	**0,61**
8	655	813	**6,3**	3,05	2,46	**0,59**
9	666	853	**5,8**	3,00	2,34	**0,66**
Average	**659**	**831**	**6,1**	**3,04**	**2,41**	**0,63**

Table 26. Saltex 6008. Fillheight 35 mm. Oposite direction

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	645	818	**6,4**	3,10	2,44	**0,66**
2	651	821	**6,3**	3,07	2,44	**0,64**
3	645	813	**6,6**	3,10	2,46	**0,64**
4	646	825	**6,0**	3,10	2,42	**0,67**
5	663	831	**6,1**	3,02	2,41	**0,61**
6	645	812	**6,3**	3,10	2,46	**0,64**
7	647	818	**6,1**	3,09	2,44	**0,65**
8	657	825	**6,3**	3,04	2,42	**0,62**
9	643	823	**6,3**	3,11	2,43	**0,68**
10	646	839	**6,1**	3,10	2,38	**0,71**
Average	**649**	**823**	**6,2**	**3,08**	**2,43**	**0,65**

Table 27. Saltex 6008. Fillheight 40 mm.

Measuring nr.	t_1 [1^{-4} s]	t_2 [1^{-4} s]	*BRD [m]*	v_1 [m/s]	v_2 [m/s]	Δv [m/s]
1	673	850	**6,9**	2,97	2,35	**0,62**
2	662	815	**7,3**	3,02	2,45	**0,57**
3	668	835	**7,1**	2,99	2,40	**0,60**
4	666	846	**6,9**	3,00	2,36	**0,64**
5	650	806	**7,2**	3,08	2,48	**0,60**
6	655	800	**7,4**	3,05	2,50	**0,55**
7	688	880	**6,8**	2,91	2,27	**0,63**
8	673	842	**7,0**	2,97	2,38	**0,60**
9	652	818	**6,9**	3,07	2,44	**0,62**
10	673	854	**6,8**	2,97	2,34	**0,63**
Average	**666**	**834,6**	**7,0**	**3,00**	**2,40**	**0,61**

Table 28. Saltex 6008. Fillheight 40 mm. Oposite direction

Måling nr	t_1 [1^{-4} s]	t_2 [1-4 s]	**BRD [m]**	v1 [m/s]	v2 [m/s]	Δv [m/s]
1	650	799	**7,1**	3,08	2,50	**0,57**
2	649	798	**7,2**	3,08	2,51	**0,58**
3	640	790	**7,2**	3,13	2,53	**0,59**
4	648	812	**6,7**	3,09	2,46	**0,62**
5	650	830	**6,9**	3,08	2,41	**0,67**
6	648	814	**6,7**	3,09	2,46	**0,63**
7	645	795	**6,7**	3,10	2,52	**0,59**
8	651	798	**6,5**	3,07	2,51	**0,57**
9	639	810	**6,4**	3,13	2,47	**0,66**
10	653	822	**6,7**	3,06	2,43	**0,63**
Average	**647**	**807**	**6,8**	**3,09**	**2,48**	**0,61**

Table 29. Saltex 6008. Fillheight 45 mm.

Måling nr	t_1 [1^{-4} s]	t_2 [1-4 s]	**BRD [m]**	v1 [m/s]	v2 [m/s]	Δv [m/s]
1	653	797	**8,2**	3,06	2,51	**0,55**
2	654	800	**7,6**	3,06	2,50	**0,56**
3	665	811	**7,8**	3,01	2,47	**0,54**
4	658	790	**8,0**	3,04	2,53	**0,51**
5	677	806	**7,7**	2,95	2,48	**0,47**
6	649	777	**8,1**	3,08	2,57	**0,51**
7	656	769	**8,2**	3,05	2,60	**0,45**
8	650	799	**7,6**	3,08	2,50	**0,57**
9	646	767	**8,2**	3,10	2,61	**0,49**
10	656	778	**8,2**	3,05	2,57	**0,48**
Average	**656**	**789**	**7,9**	**3,05**	**2,53**	**0,51**

Table 30. Saltex 6008. Fillheight 45 mm. Oposite direction

Måling nr	t_1 [1^{-4} s]	t_2 [1-4 s]	**BRD [m]**	v1 [m/s]	v2 [m/s]	Δv [m/s]
1	646	763	**8,5**	3,10	2,62	**0,47**
2	646	757	**8,4**	3,10	2,64	**0,45**
3	650	752	**8,9**	3,08	2,66	**0,42**
4	650	773	**8,2**	3,08	2,59	**0,49**
5	660	779	**8,1**	3,03	2,57	**0,46**
6	647	776	**7,7**	3,09	2,58	**0,51**
7	650	754	**8,3**	3,08	2,65	**0,42**
8	655	760	**8,5**	3,05	2,63	**0,42**
9	656	766	**8,2**	3,05	2,61	**0,44**
10	655	766	**8,4**	3,05	2,61	**0,44**
Average	**652**	**765**	**8,3**	**3,07**	**2,62**	**0,45**

APPENDIX 2, RESULTS SHOWN IN DIAGRAMS

The values for BRD and VC from tabl 1- 12 are plotted in diagram 1. Together with the measured values for BRD and VC, the standard deviation, geometric trend line and R squared are calculated.

Diagram 1 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for artificial grass fields.

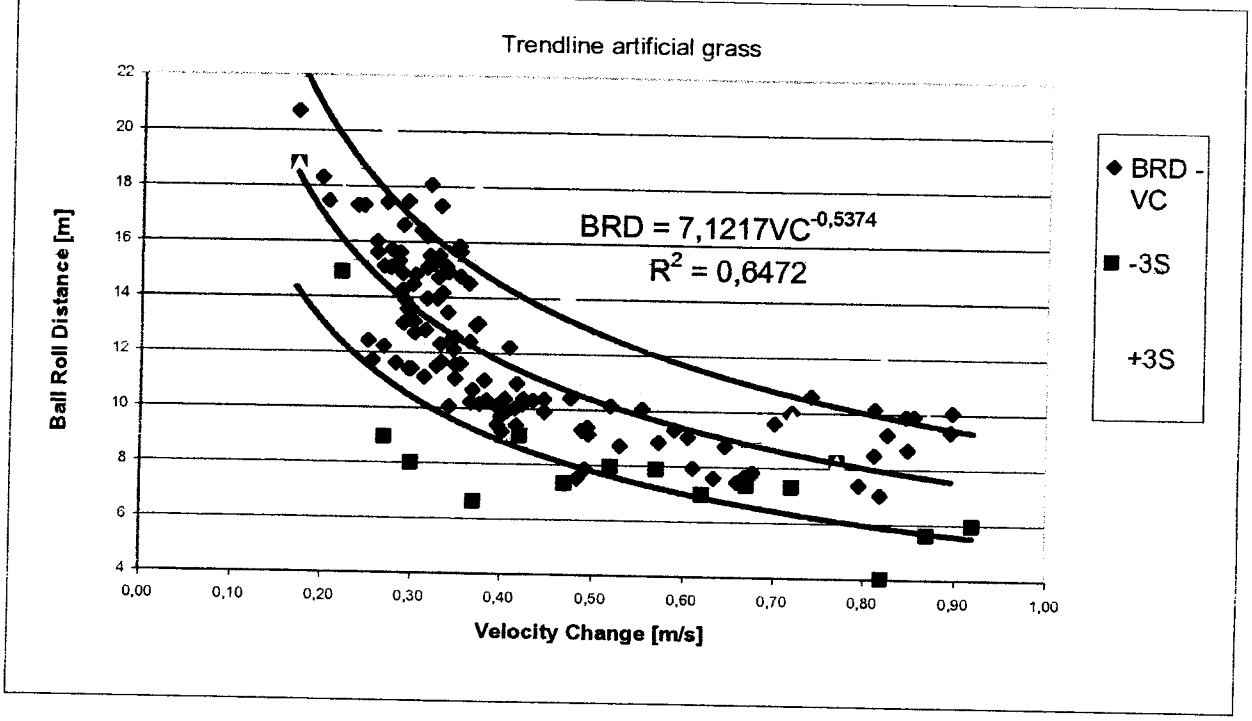


Diagram 2 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for artificial grass fields longitudinal

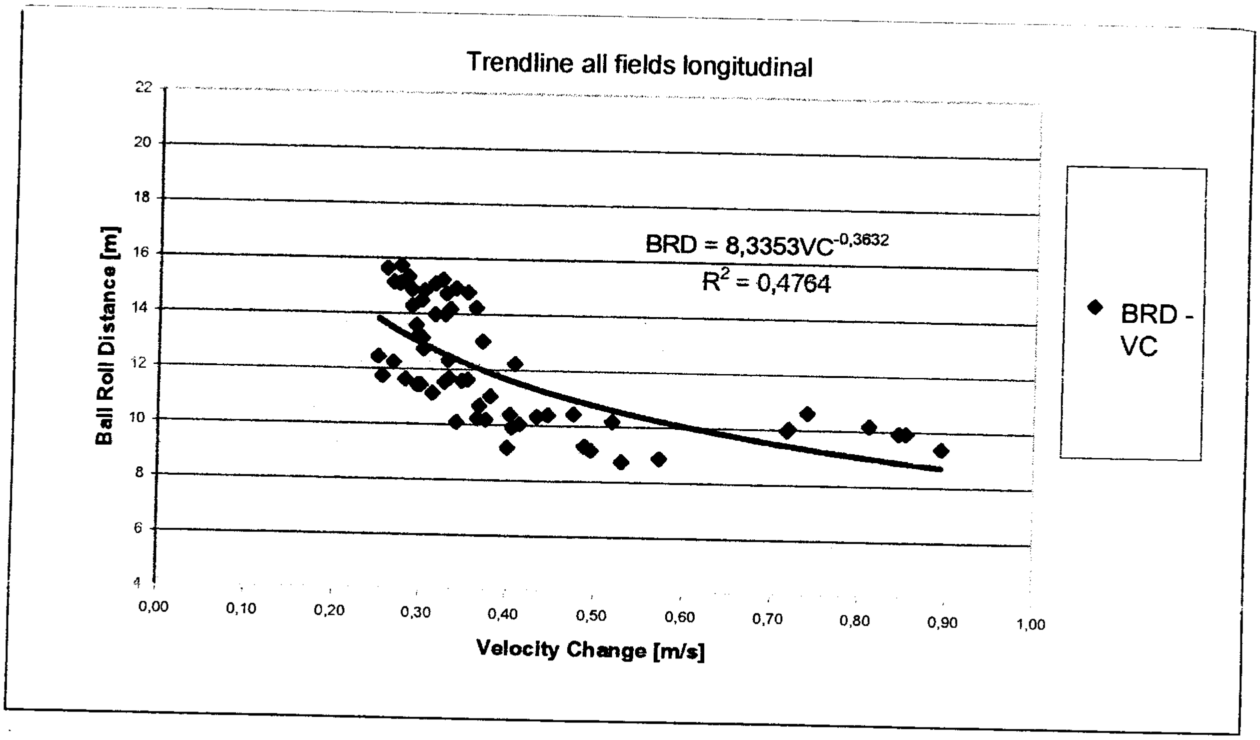


Diagram 3 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for artificial grass fields transversal with the slope.

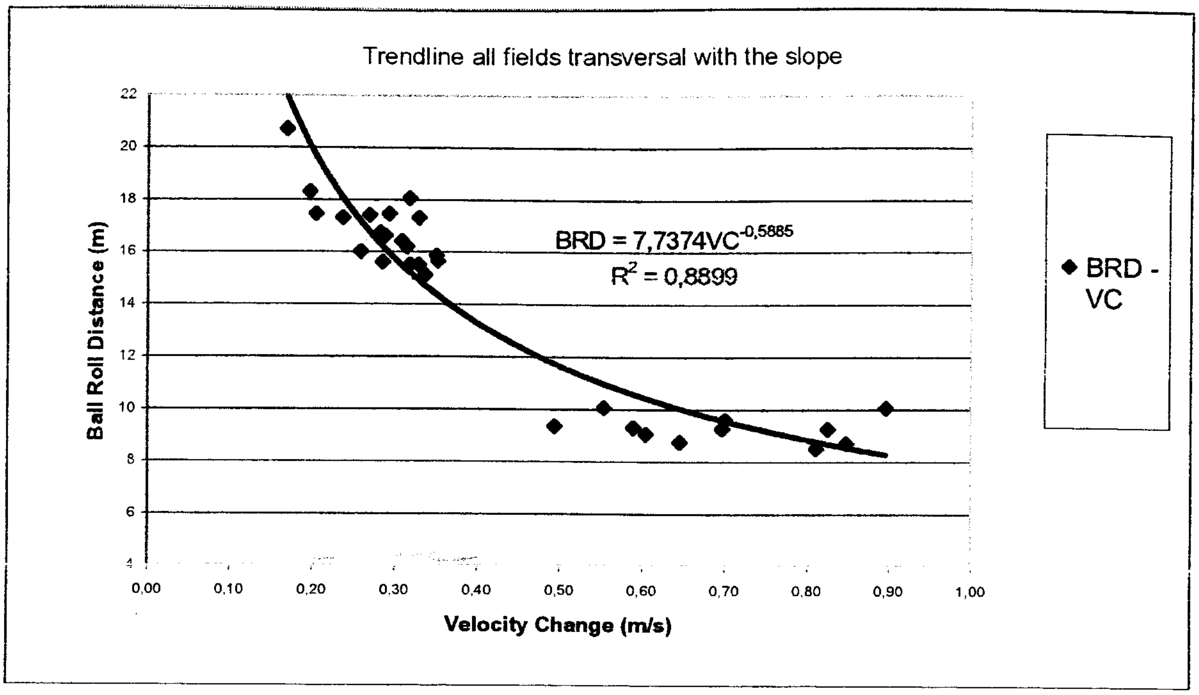


Diagram 4 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for artificial grass fields transversal against the slope.

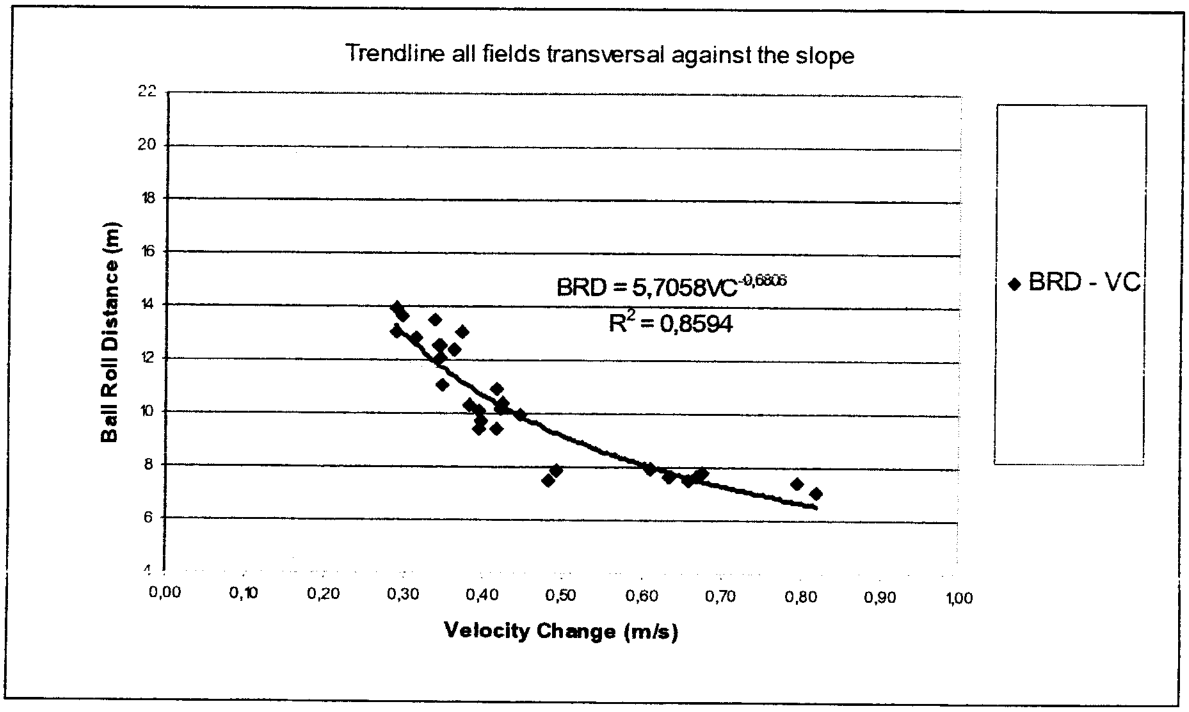


Diagram 5 shows the connection between Ball Roll Distance and Velocity Change for natural fields

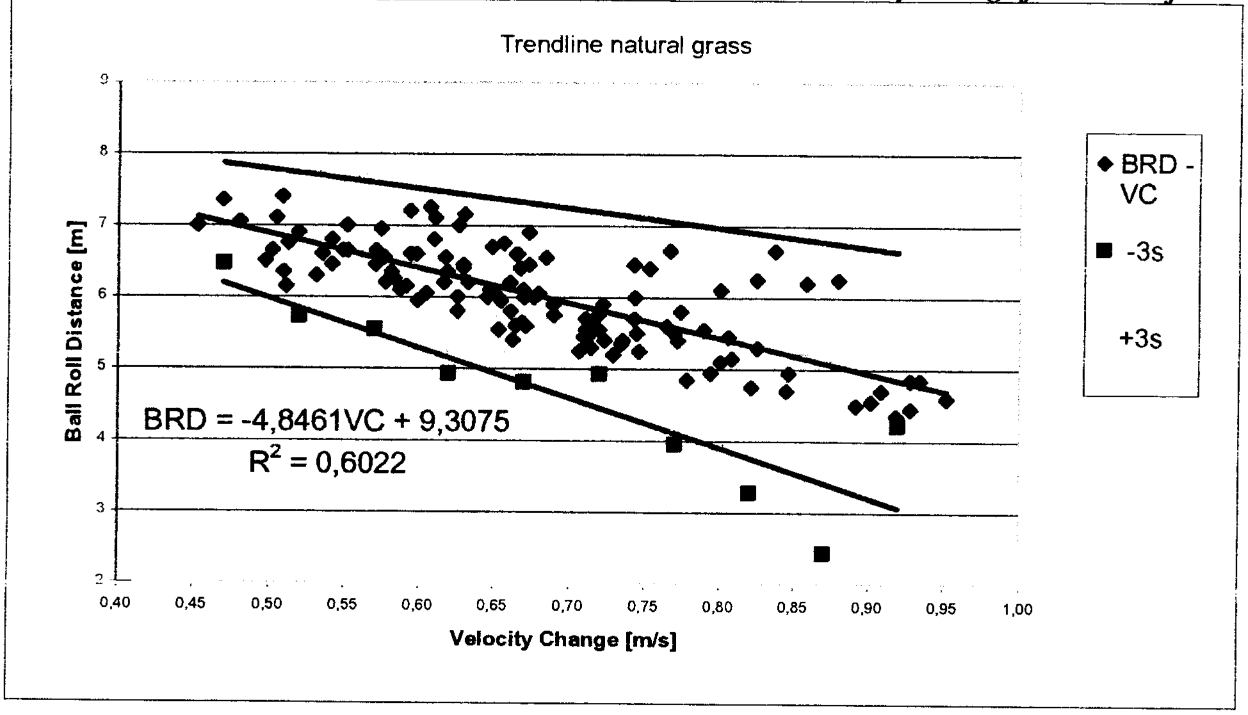


Diagram 6 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for natural grass fields longitudinal.

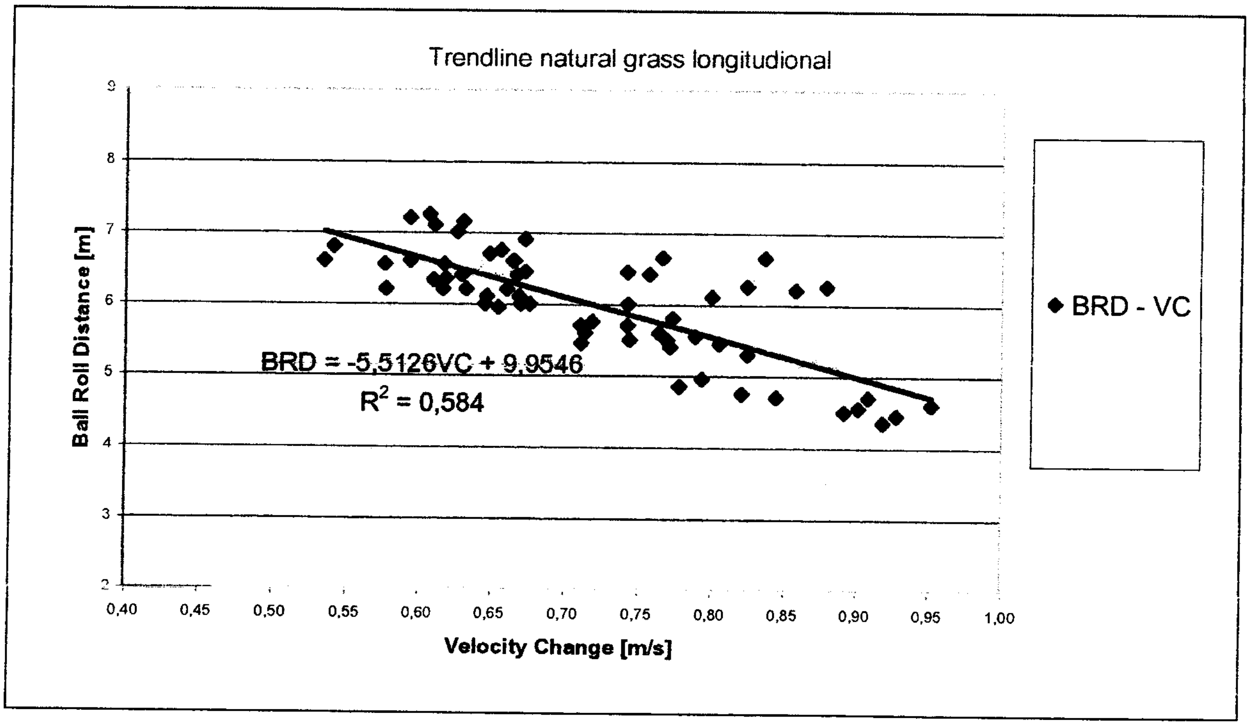


Diagram 7 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for natural grass fields transversal with the slope.

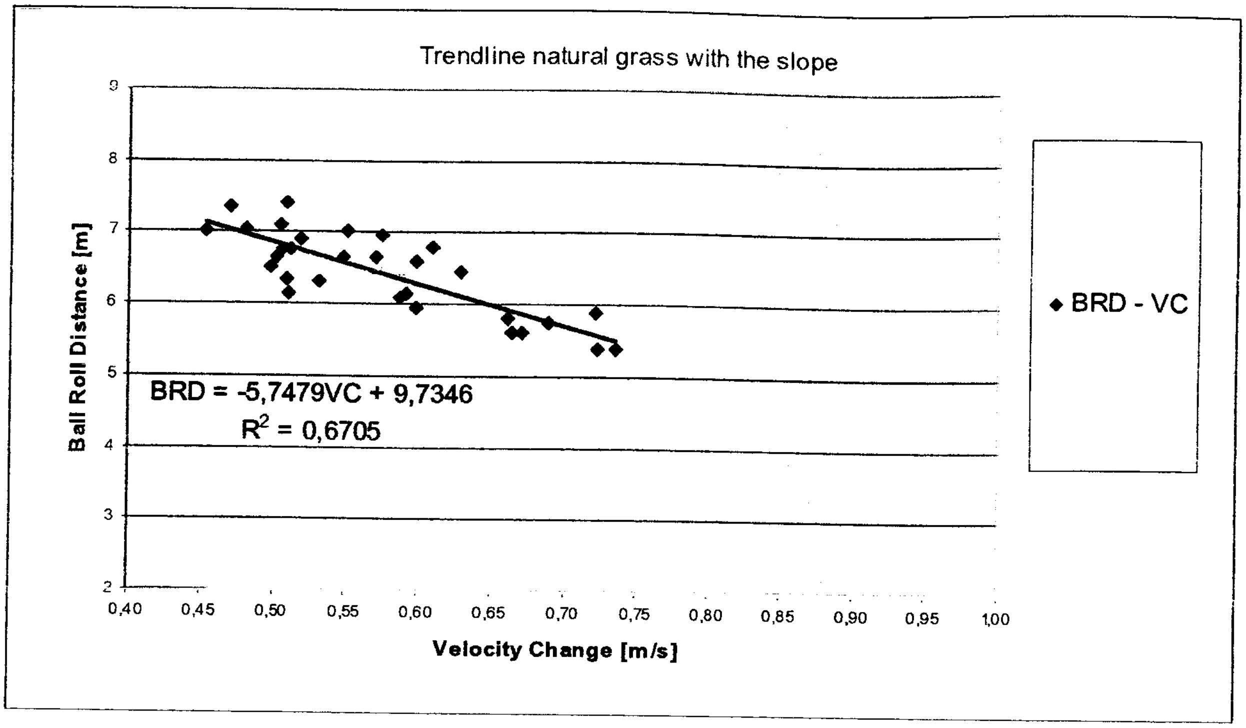


Diagram 8 shows the connection between Ball Roll Distance (BRD) and Velocity Change(VC) for natural grass fields transversal against the slope.

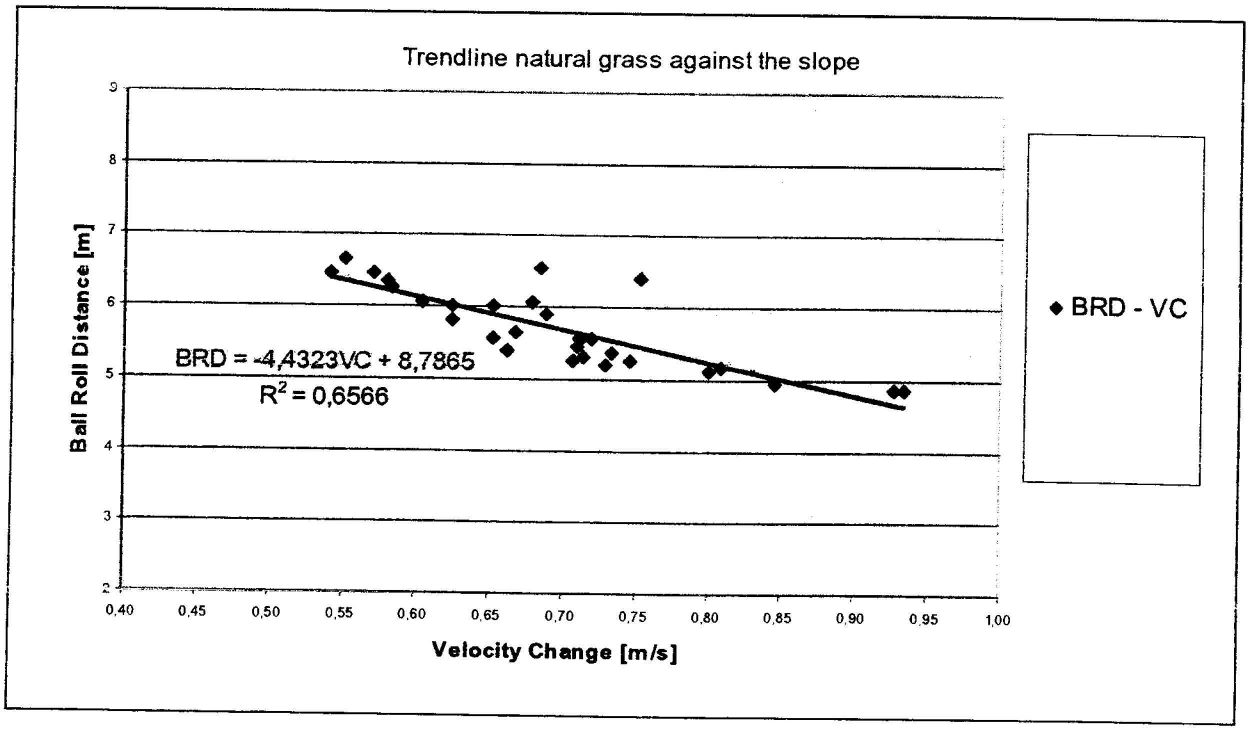
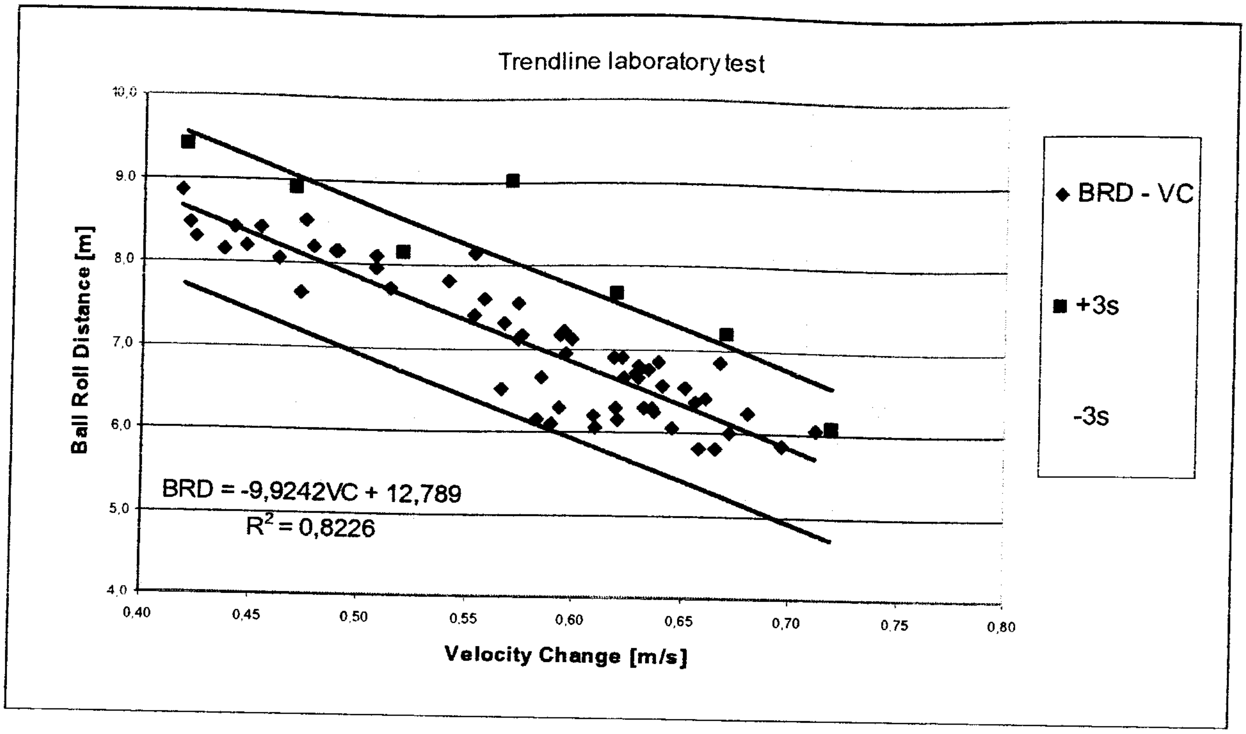
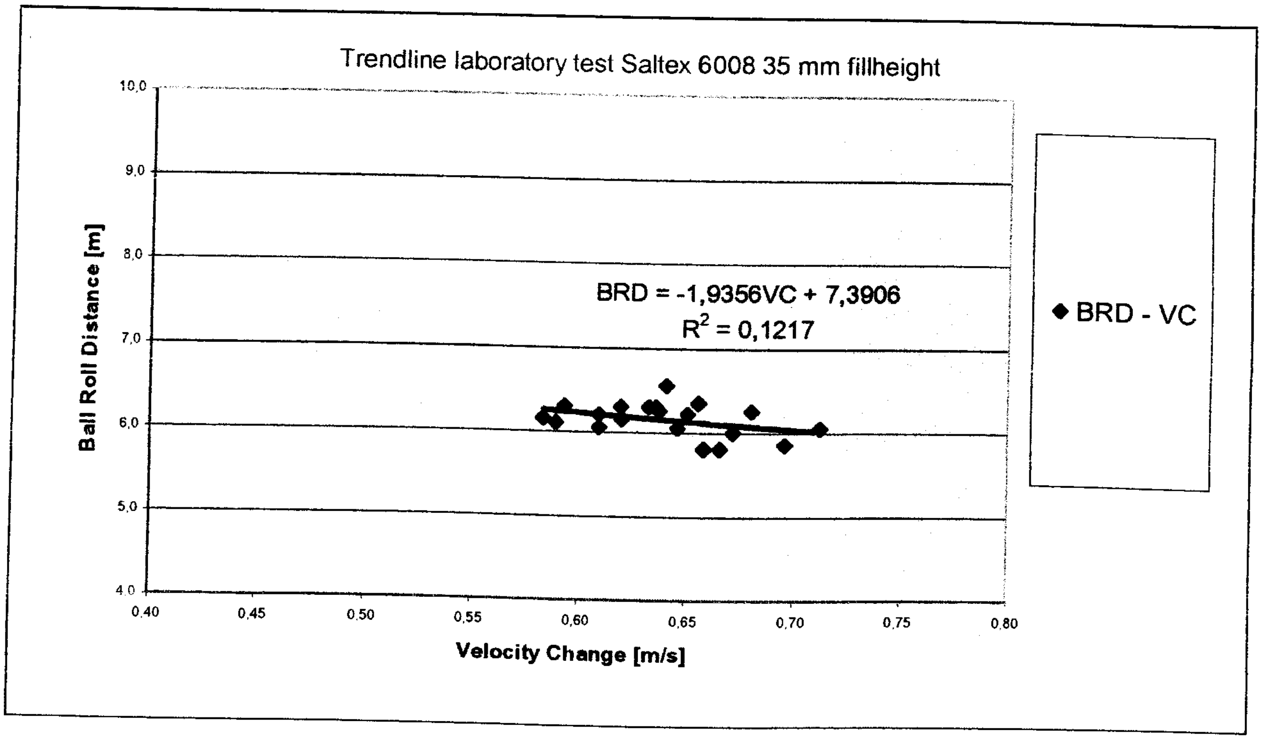
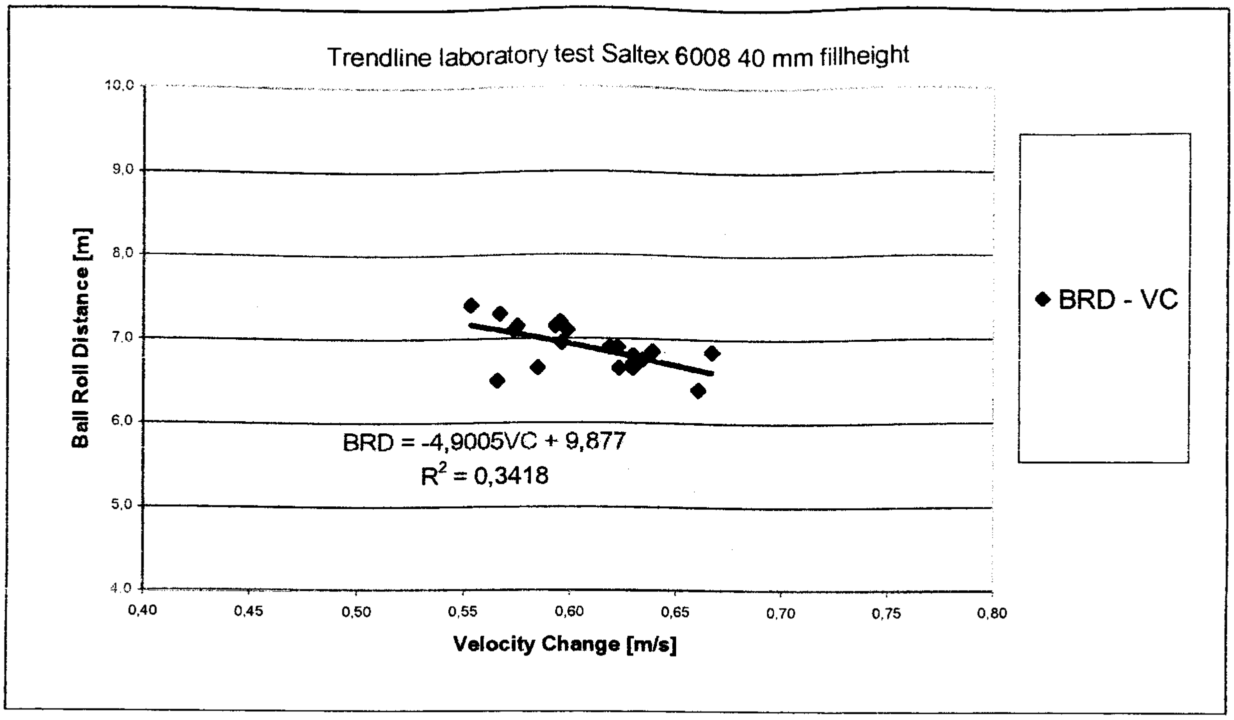
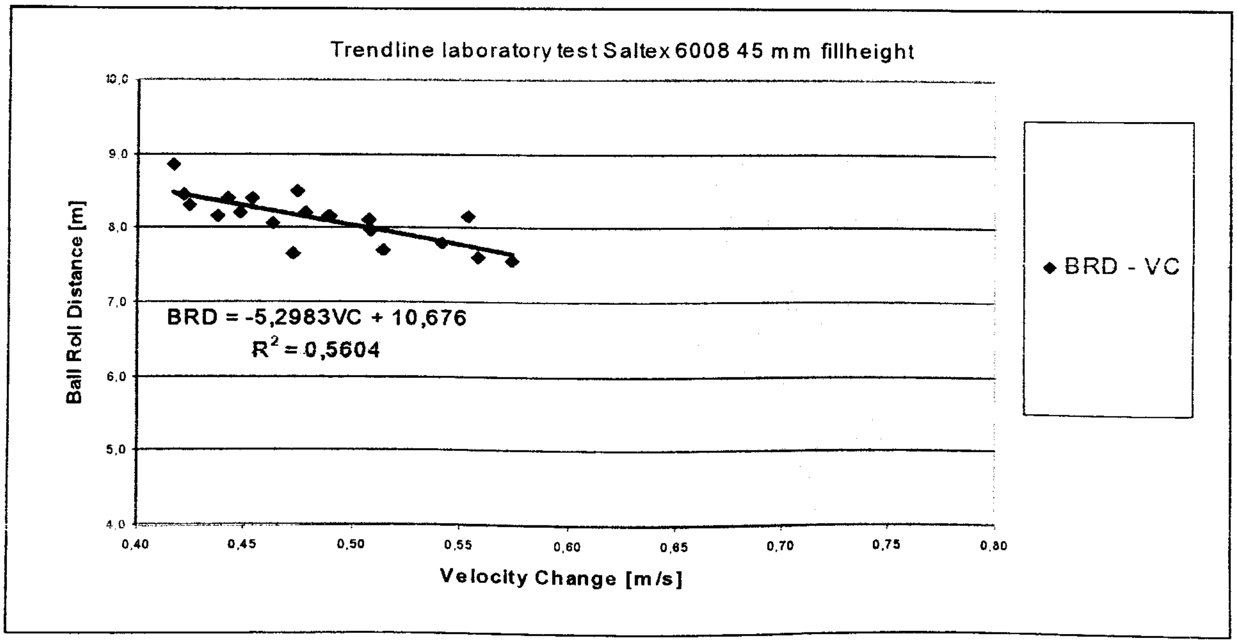


Diagram 9 shows the connection between Ball Roll Distance (BRD) and Velocity change for laboratory all tests. The following diagrams shows the results for the different fill heights.






Trendline laboratory test Saltex 6008 40 mm fillheight
Ball Roll Distance [m]
10,0
9,0
8,0
7,0
6,0
5,0
4,0
BRD = -4,9005VC + 9,877
R2 = 0,3418
0,40
0,45
0,50
0,55
0,60
0,65
0,70
0,75
0,80
Velocity Change [m/s]
BRD - VC


Trendline laboratory test Saltex 6008 45 mm fillheight
Ball Roll Distance [m]
10,0
9,0
8,0
7,0
6,0
5,0
4,0
BRD = -5,2983VC + 10,676
R2 = 0,5604
0,40
0,45
0,50
0,55
0,60
0,65
0,70
0,75
0,80
Velocity Change [m/s]
BRD - VC