DESIGN OF ROLLER SKIING course

Considerations, calculations, guidelines

Cross Country Ski Center main purpose

1) It’s a venue for hosting ski competitions

2) It’s a place for all-season training for skiers

3) Ski Center may be used as a recreational area for general public and to popularize healthy life style

FIS ICR: 396.4 Course Design Standards

- 396.4.1 Rollerski competitions are held on **asphalt or similar artificial or natural surfaces** which that are hard packed.
- 396.4.2 The course must be designed with the **highest priority being given to the safety of competitors**.
- 396.4.3 **Obstacles or hazardous objects along or beside the track must be removed**, or if not possible, they must be clearly marked and where necessary protected by padding.
- 396.4.4 The course has to must be **at least 4 meters wide**.
- 396.4.5 The downhill sections must **not have any sharp curves**.
- 396.4.6 Warm up and cool down areas must exist and be secured

FIS ICR: 396.8 Start and Finish Requirements

- 396.8.1 The start line must be clearly marked on the surface using paint.
- 396.8.1.1 Mass start areas must be a minimum of 6 m wide in order to permit a fair start.
- 396.8.1.2 At mass start competitions, a no skating zone must be clearly marked is not permitted for the first 50-70 m after the start.
- 396.8.1.3 Handicap starts must have a minimum of two corridors that are a minimum of 10 m in length and each corridor must be a minimum of 2 m wide.

DIFFERENCE BETWEEN XC SKI COURSE & ROLLER SKI course

1. Depending or rollerski type athlete's velocity can be much higner than skiing on snow
2. The course surface is solider and rougher
3. The athletes wear less clothes

- Health risks and consequence of athlete's falling is much more serious on (or outside) rollerski course
- In addition the rollerskis don't have steering wheels and brakes.
- The athlete can't use alpine techniques to change direction and to reduce velocity

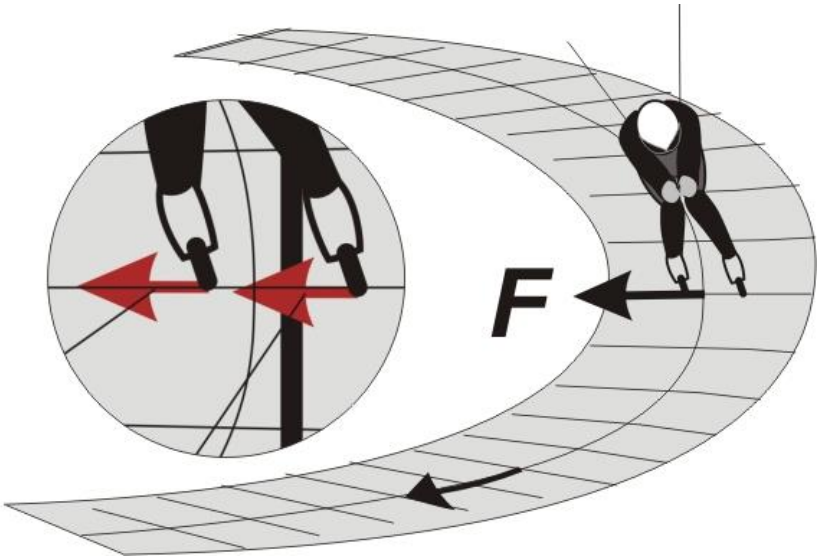
How to design high speed and safe curve on roller course?

- Due to be suitable for training roller course must make physical demands to athletes and must be safety for them. Sometimes these are contradictory requirements.
- To be hard enough for training roller course should have the same height parameters as cross country ski course has. (In the whole the TC should be 3-4% of course length).
- As a rule the **homologated ski course** may be located on rollerski course in winter. So the A and B climbs should be included in it.
- For safety reasons down hills have to be gently sloping and straight.
- But too gently down hill takes too much length of course. For example 4%-down hill (athletes can reach more than 10 m/sec velocity and move passive without using his own means of propulsion) with HD=30 m takes 750 meters of course length. It's too much to make enough difficult course. And it's too simple down hill for athletes.
- Also the course can't be absolutely straight. Some curves are necessary.

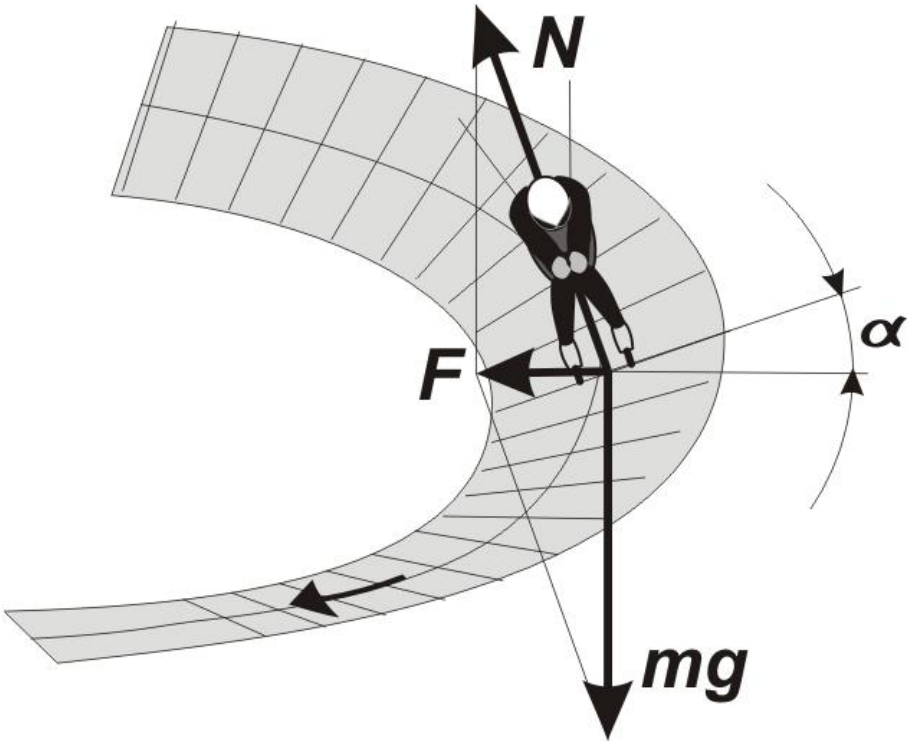
•The athlete on curve moves with centripetal acceleration which creates by ***F***

•There are two ways to create centripetal force by friction (on flat curve) and by vector sum of gravity force ***mg*** and normal pressure force ***N*** (on banking curve).

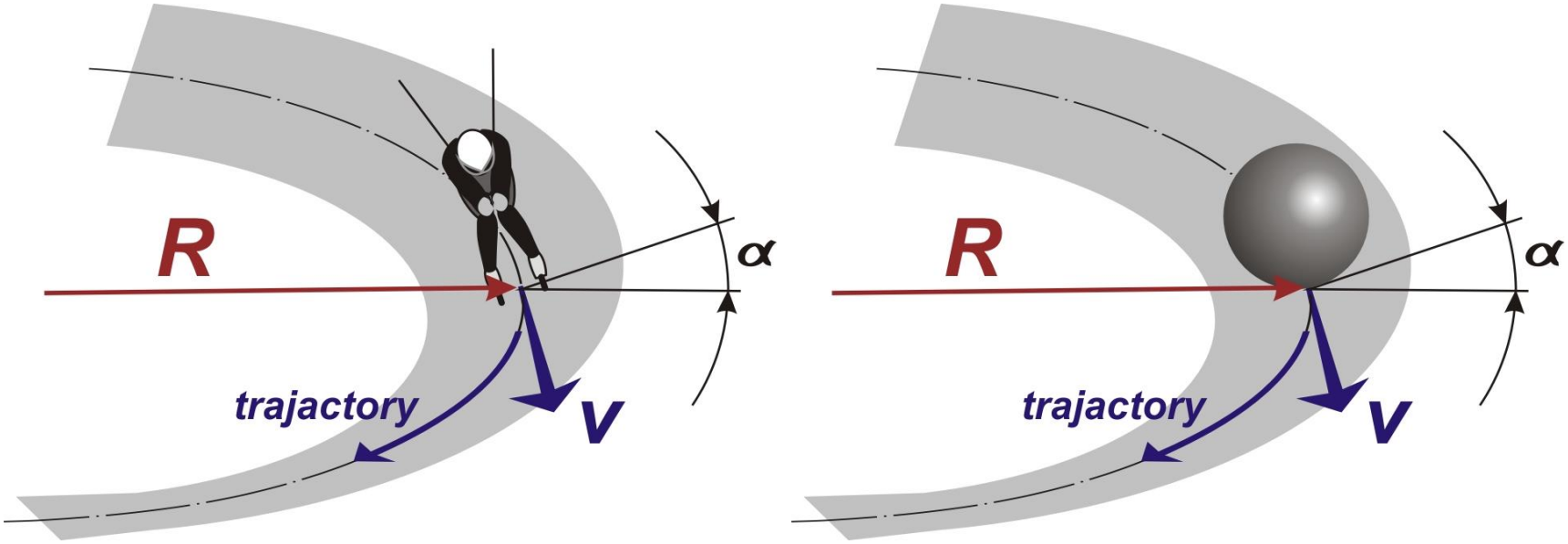
Flat curve



Curve with banking



So the banking is the main means to design a fast and safe curve.
Banking what is calculated by this formula is condition that any physical agent (not athlete only) passes curve without any additional influence..

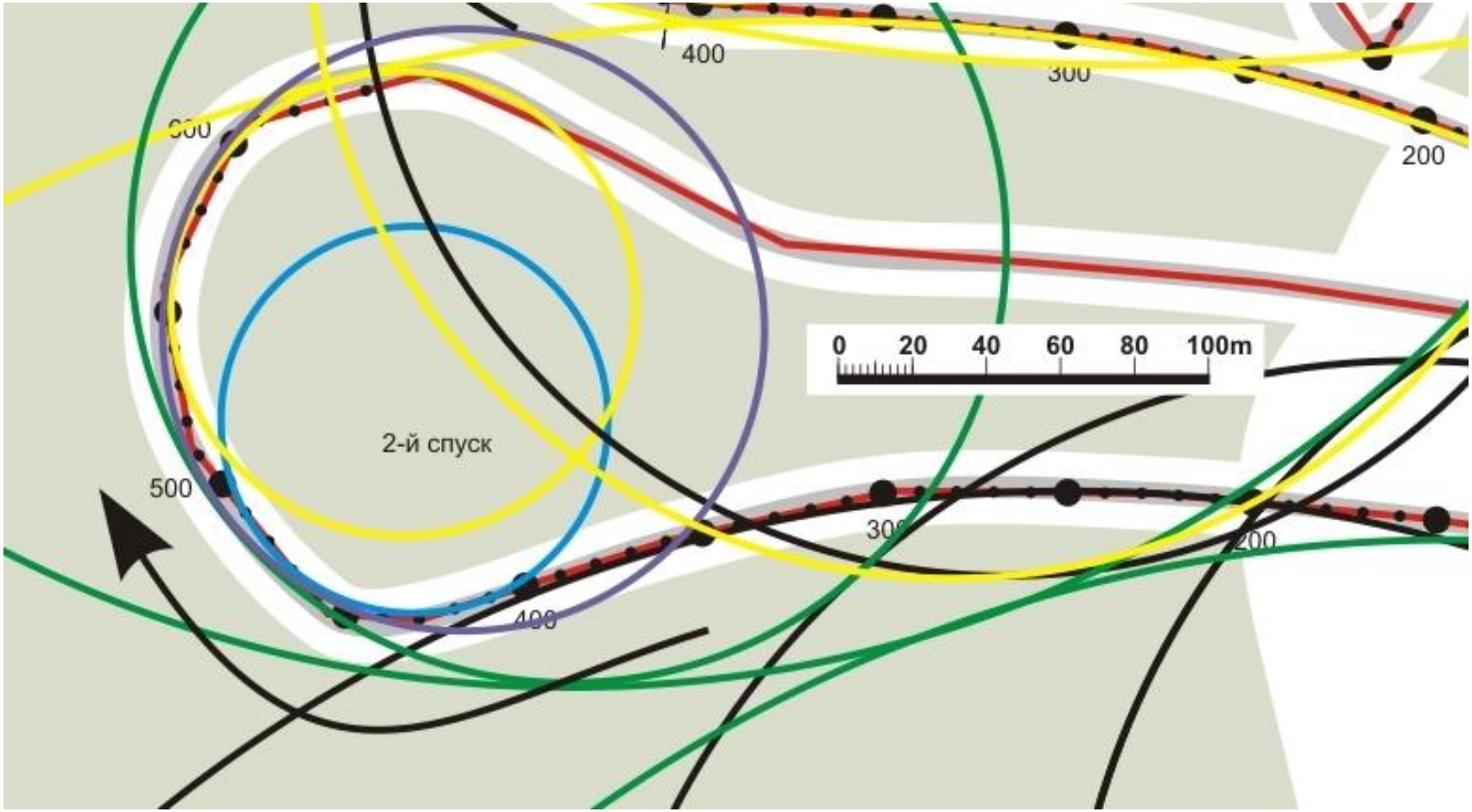


$$\alpha_{\%}=V^2/(10R) \quad (\%)$$

In order to passing not only with maximum (calculated) speed recommended banking should be decreased about 30%:

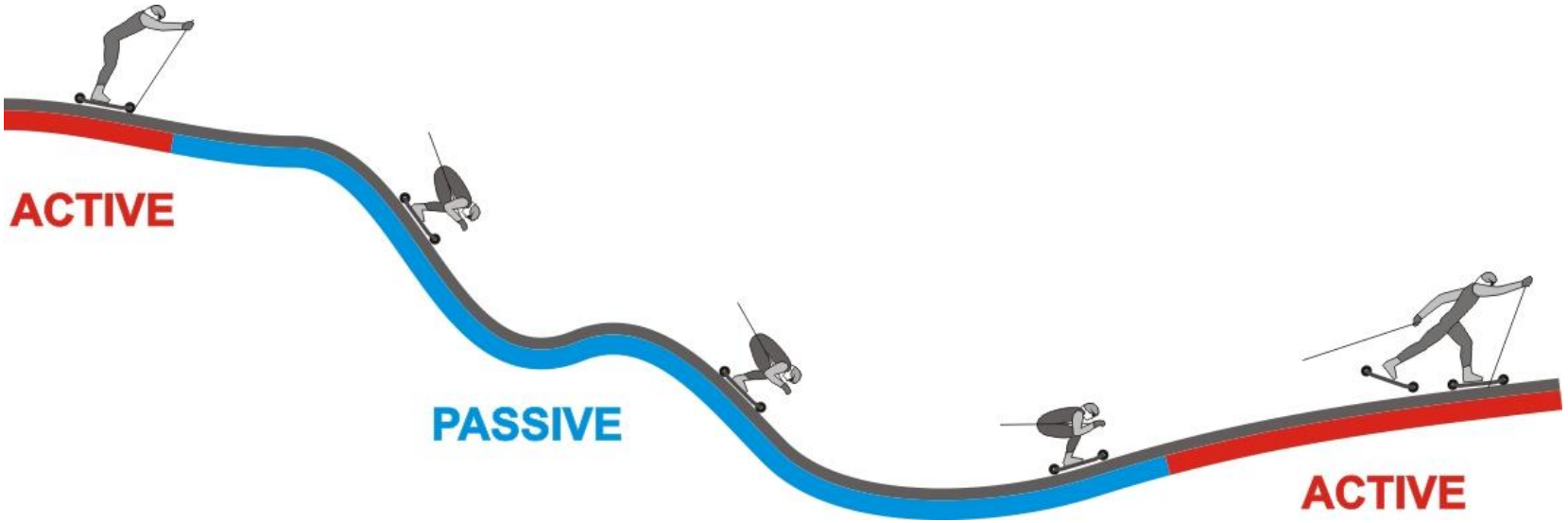
$$\alpha_{\%}=0,7*V^2/(10R) \quad (\%)$$

Curve radius ***R*** for this formula may be taken right from draft plan of course by measuring inscribed circle radius subject to map scale.



What about ***V*** ?

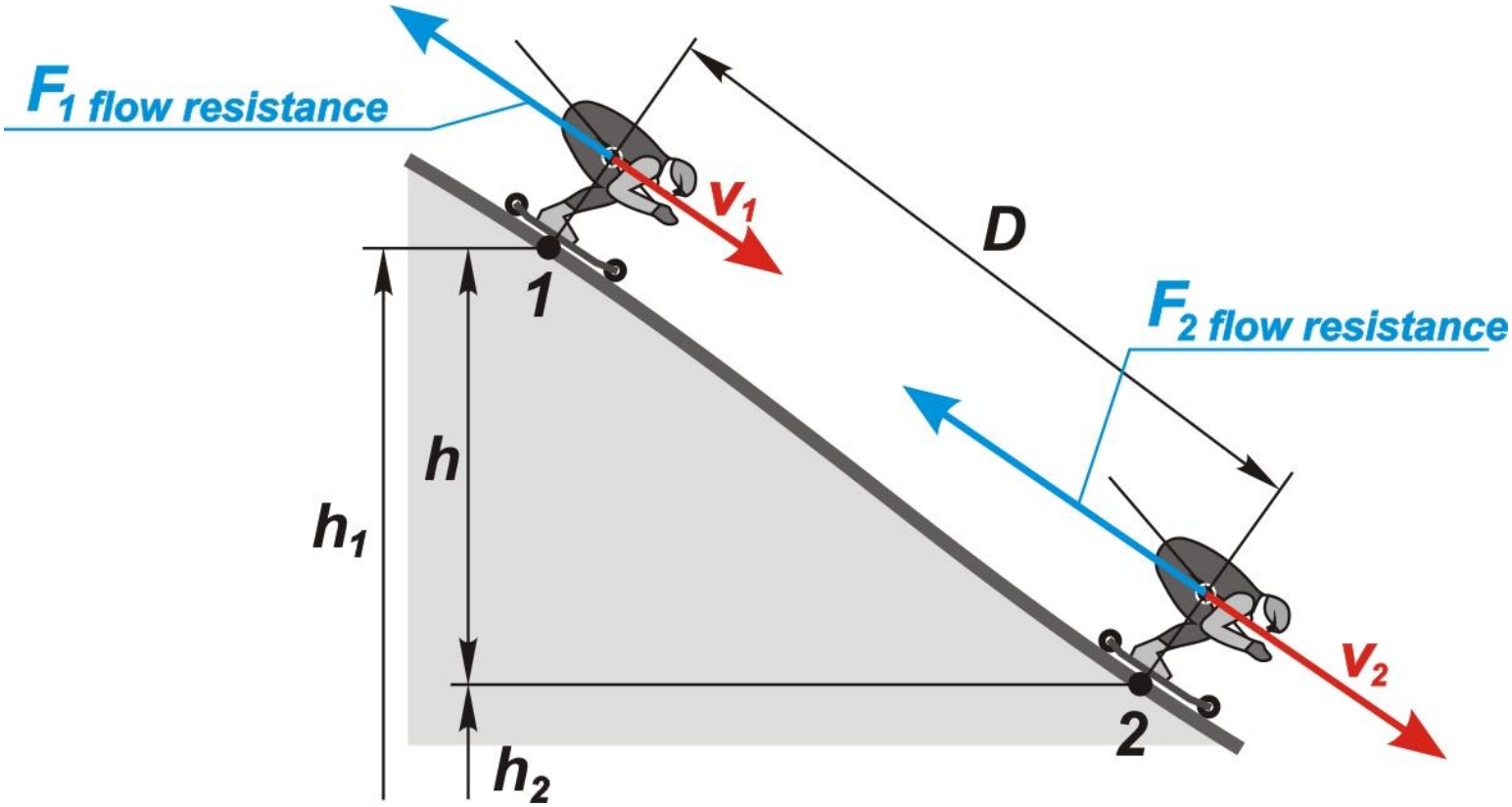
- First of all this method is suitable for passive movement when athlete moves without using his own means of propulsion. This condition begins when athlete's velocity reaches 6-8 or even 10 (for skating technique) meters per second.



Blue line marks the field of application of the method.

The problem is that we need to know air flow resistance force to calculate the athlete's velocity. But this force in turn depends on athlete's velocity.

We calculate velocity change on small part of down hill (***D***) where air flow resistance force may be considered as a constant. Next we'll calculate new air flow resistance force in accordance with new velocity and will calculate velocity change on next small part of down hill and so on.



$$V_2 = \sqrt{0{,}95V_1^2 + 20h - 4}$$

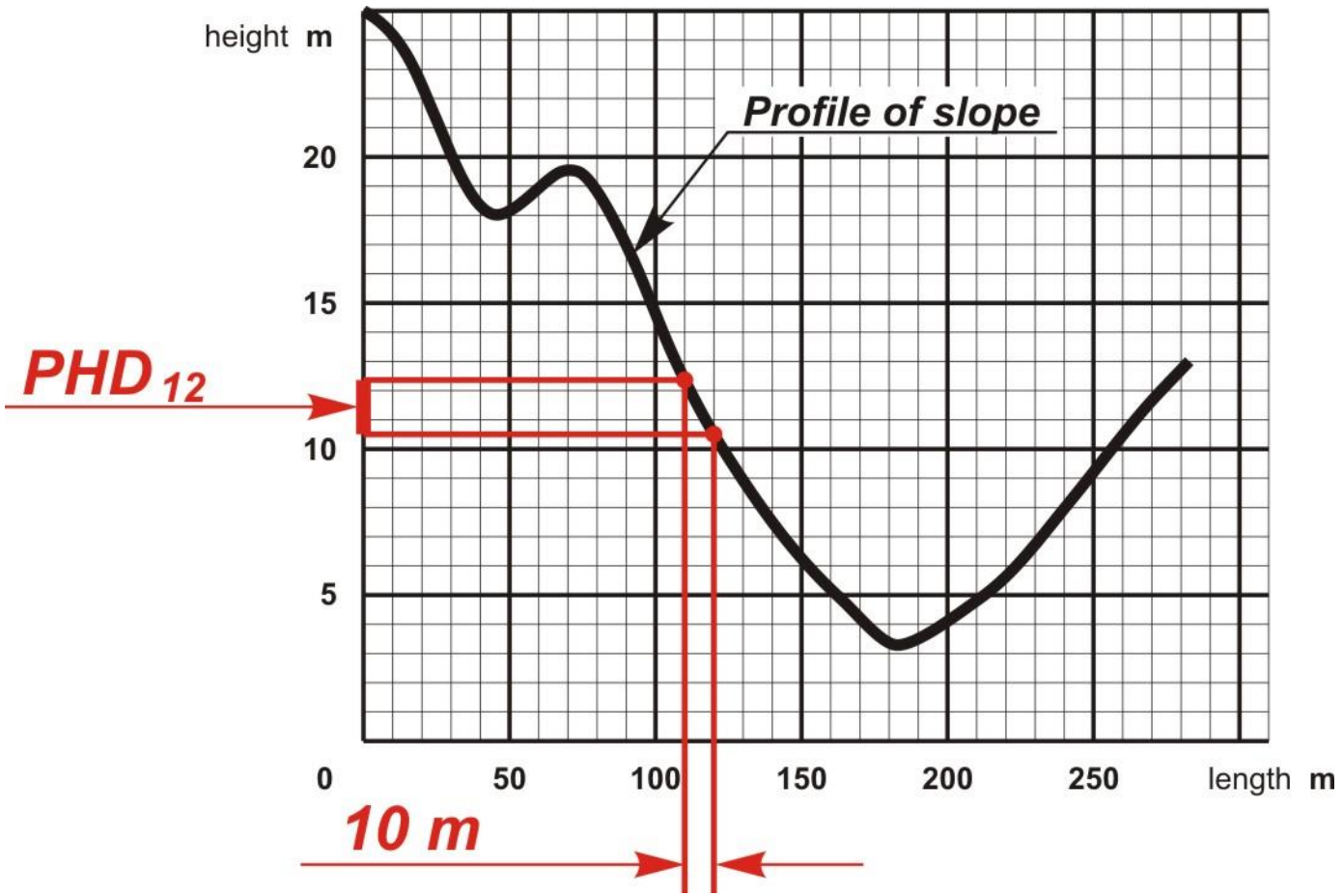
This formula enables to calculate velocity in the end of small part knowing velocity in the beginning of part and PHD of this part.

How to use it?

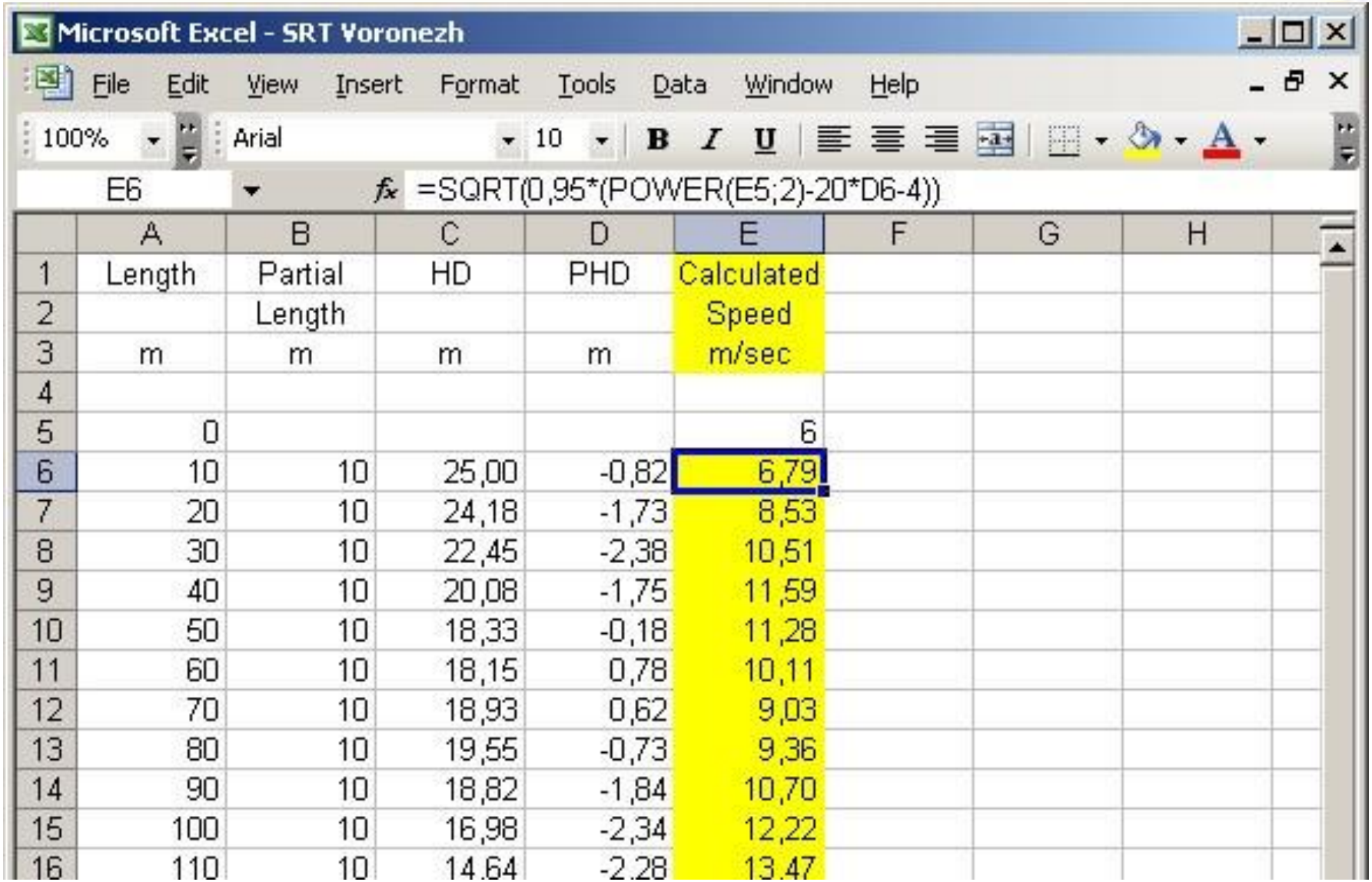
Rollerski velocity calculation procedure

1) We need to make protocol of downhill profile with PHD for each ten meters of length (Size D equal ten meters).
2) It may be made mathematically or graphically.
3) Of course the necessity to have profile data in such format is a disadvantage of this method.

Graphic example of slope height profile



EXAMPLE OF EXCEL FORM FOR DOWNHILL SPEED CALCULATION



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100% Arial 10 B I U

E6 =SQRT(0,95*(POWER(E5;2)-20*D6-4))

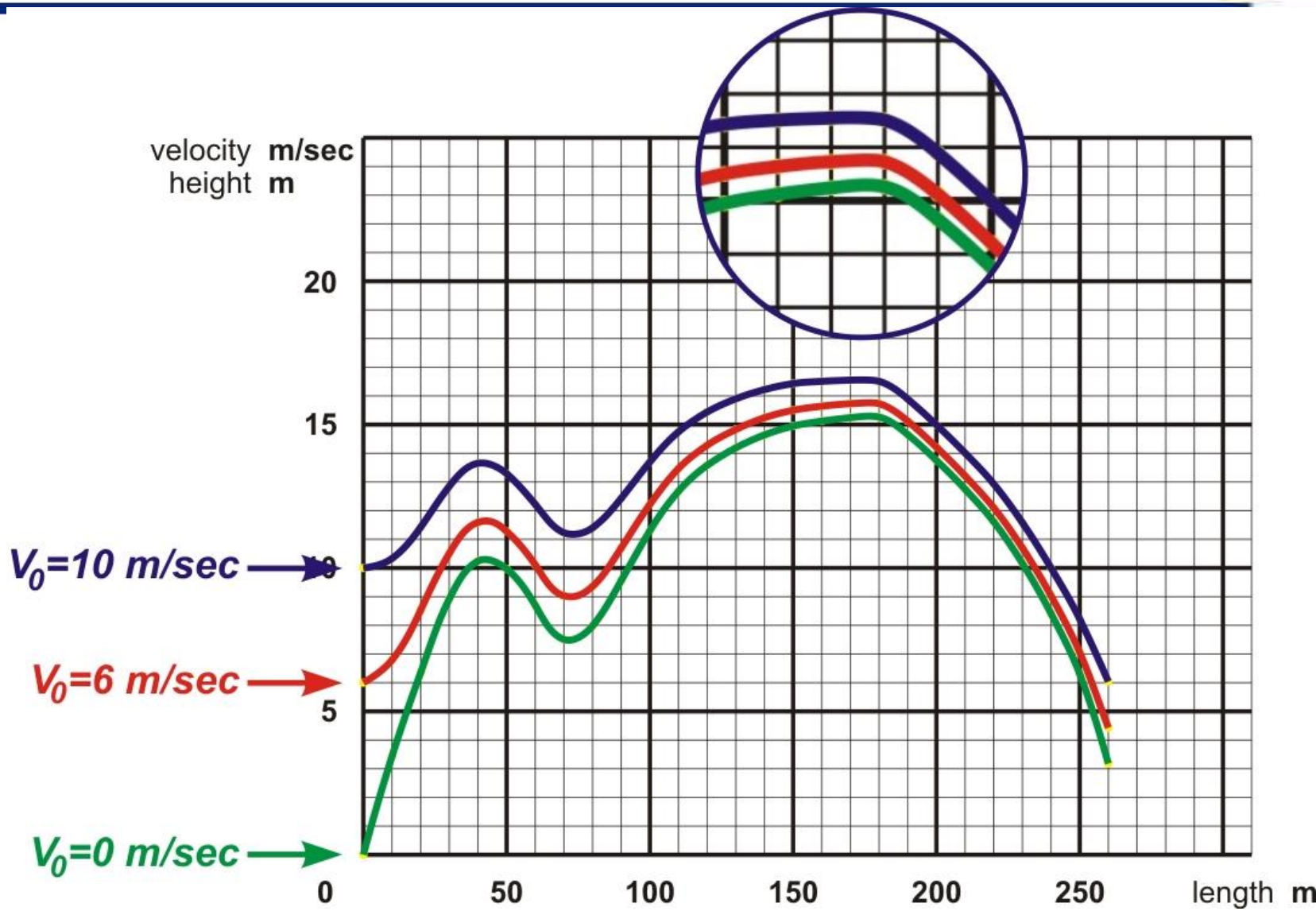
	A	B	C	D	E	F	G	H
1	Length	Partial	HD	PHD	Calculated			
2		Length			Speed			
3	m	m	m	m	m/sec			
4								
5	0				6			
6	10	10	25,00	-0,82	6,79			
7	20	10	24,18	-1,73	8,53			
8	30	10	22,45	-2,38	10,51			
9	40	10	20,08	-1,75	11,59			
10	50	10	18,33	-0,18	11,28			
11	60	10	18,15	0,78	10,11			
12	70	10	18,93	0,62	9,03			
13	80	10	19,55	-0,73	9,36			
14	90	10	18,82	-1,84	10,70			
15	100	10	16,98	-2,34	12,22			
16	110	10	14,64	-2,28	13,47			

Consequences of using this method

- 1. If athletes begin to move with different initial velocity and move PASSIVE, the difference between their velocities decreases.
- In this picture there are three graphs showing velocities of athletes who began their passive movement with different initial velocities: 0, 6 and 10 meters per second. As you can see the difference between velocities after 180 meters decreases from 10 meters to less than 1.5 meters and continues to decrease.
- This means that we shouldn’t worry about accuracy of initial speed. 6 m/sec would be good for most of cases.
- The steeper the downhill the stronger the “speed difference decrease effect”.

(see next slide)

Difference between starting velocities



TAILWIND INFLUENCE

To research the tailwind influence on the athlete's velocity our formula has to be transformed a little:

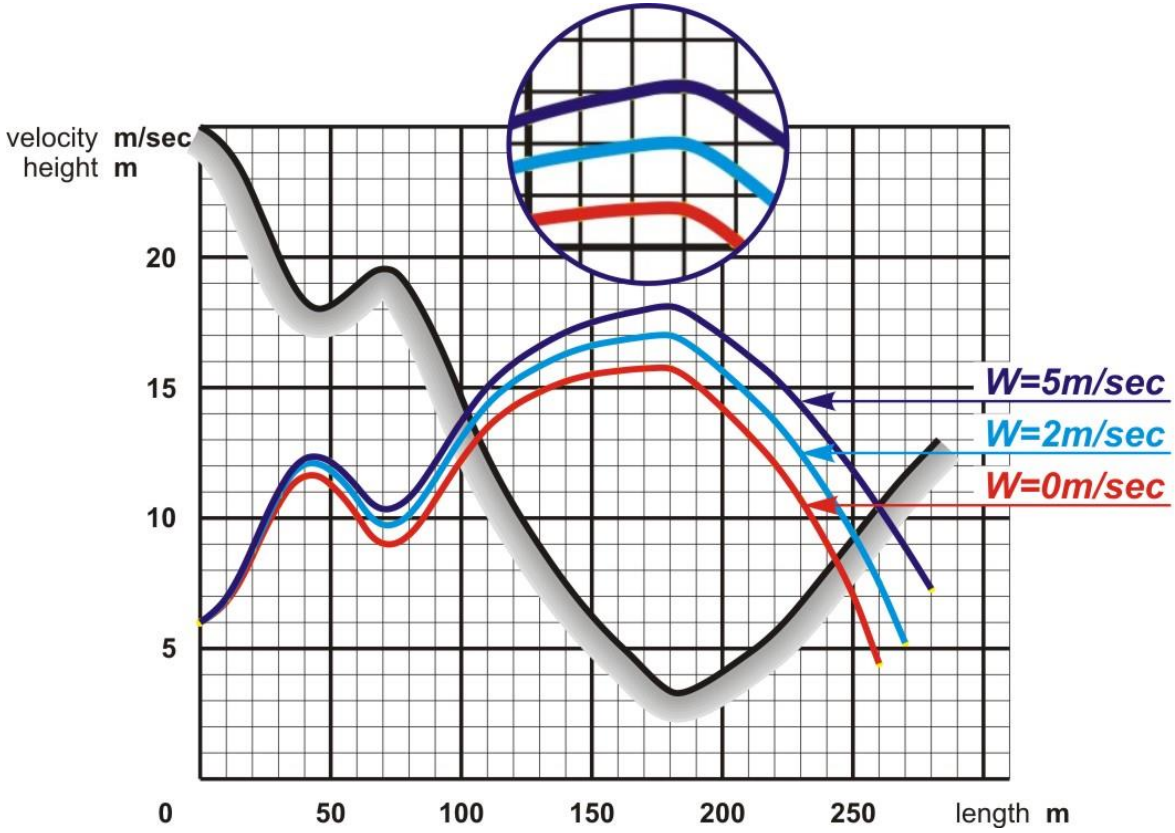
$$V_2 = \sqrt{0{,}95V_1^2 + 20h - 4}$$

$$V_2 = \sqrt{V_1^2 - 0{,}05(V_1 - W)^2 + 20h - 4}$$

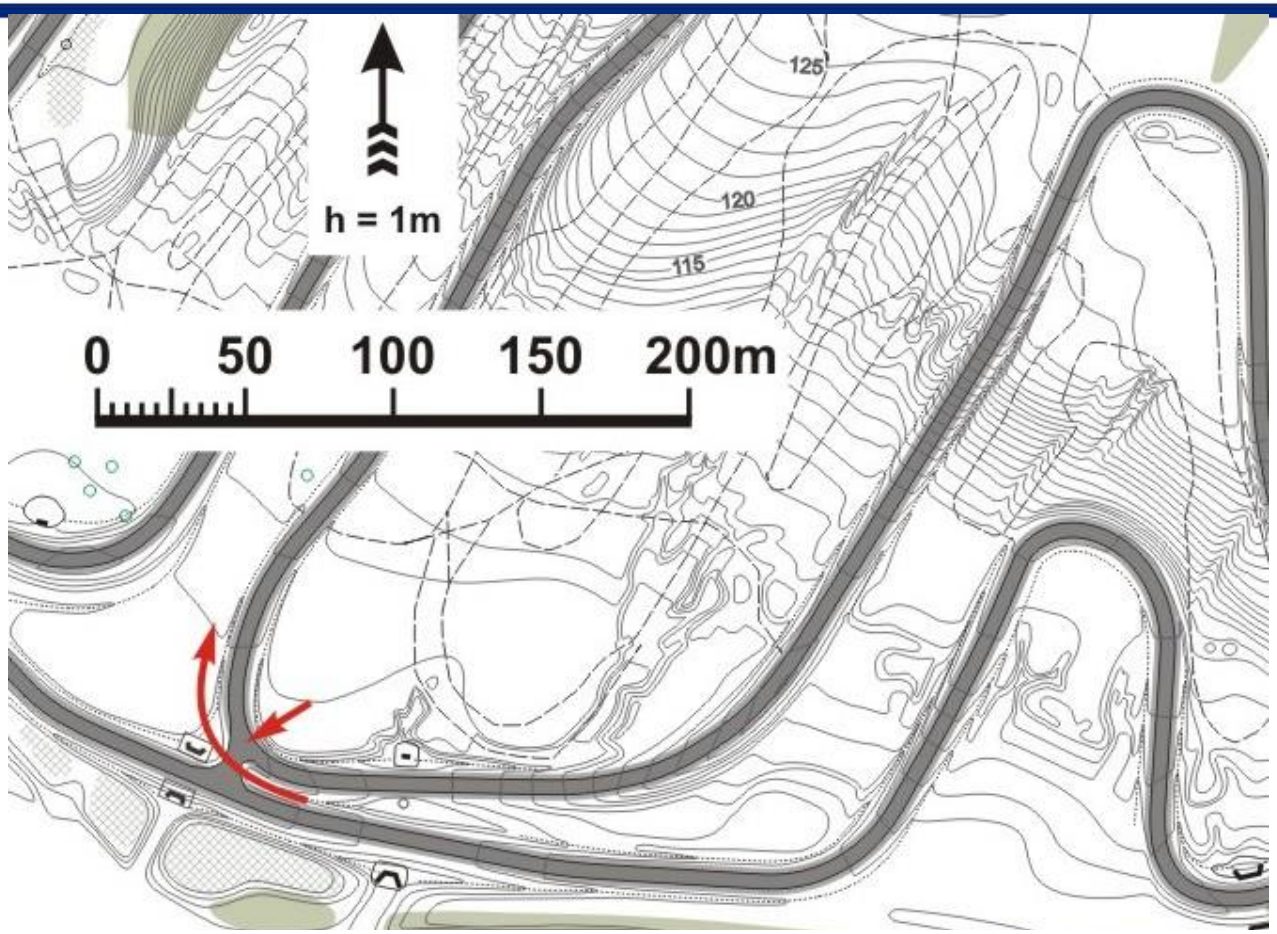
W – tailwind velocity

WEAK TAILWIND GIVES ESSENTIAL GROWTH OF VELOCITY

- As we can see a weak tailwind of 2 m/sec adds more than 1m/sec athlete's speed in critical point
- Also not strong wind of 5 m/sec adds more than 2m/sec athlete's speed in critical point



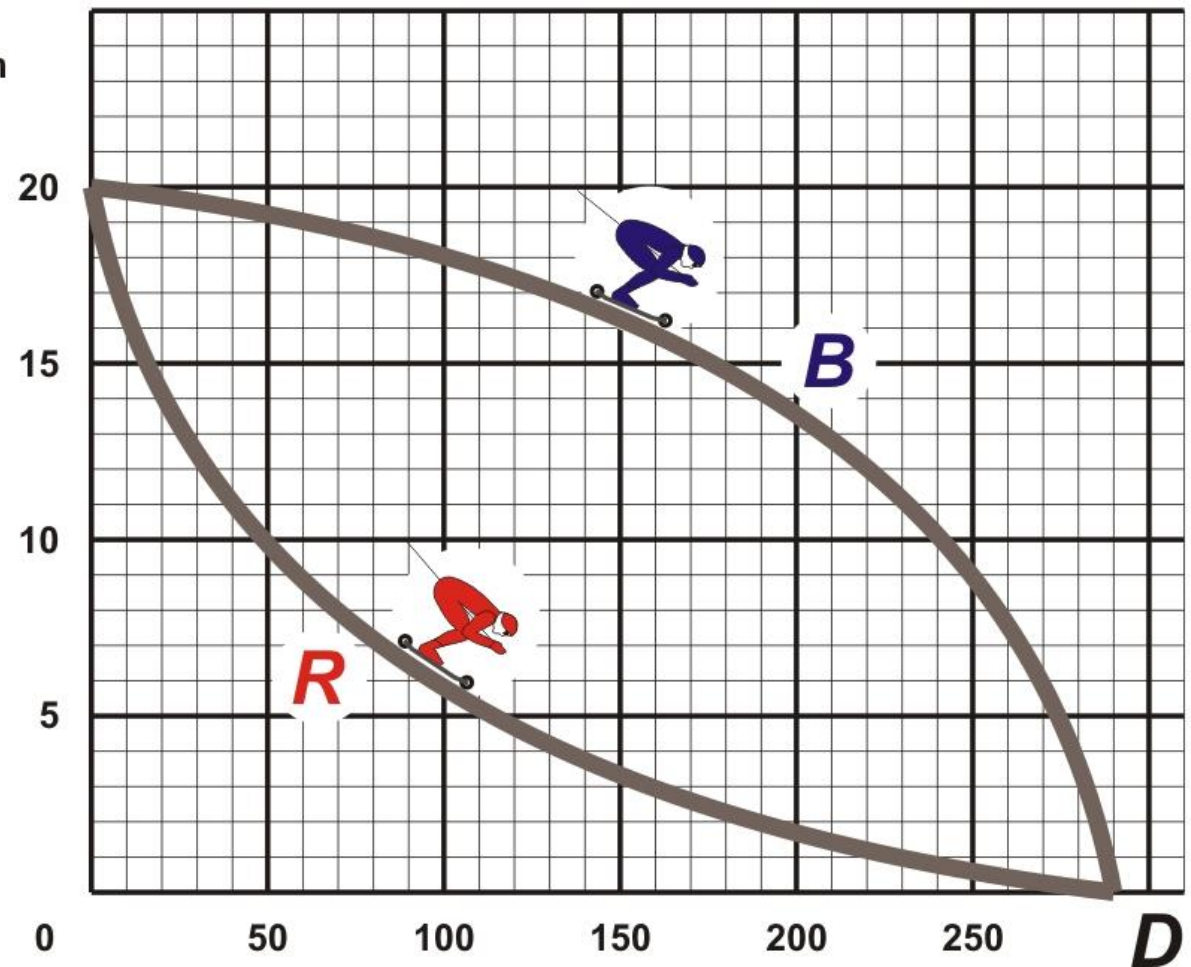
EXAMPLE OF DEMINO RYBINSK (RUS) ROLLERSKI COURSE curve



During the designing this curve was not considered as the one passed passively. Five years RT was used without any accidents. During horrible hurricane in June 2010 almost all trees were destroyed. Just after that athletes started to fall in this place. Research shows that the tailwind was the reason for the accidents.

SOME PRACTICAL EXERCISE

There are two different down hills (A and B) with the same HD, length and average gradient. **Questions**:
1) Which athlete will reach bottom of slope (point D) earlier?
2) Whose speed at point D will be faster?
3) How much faster?



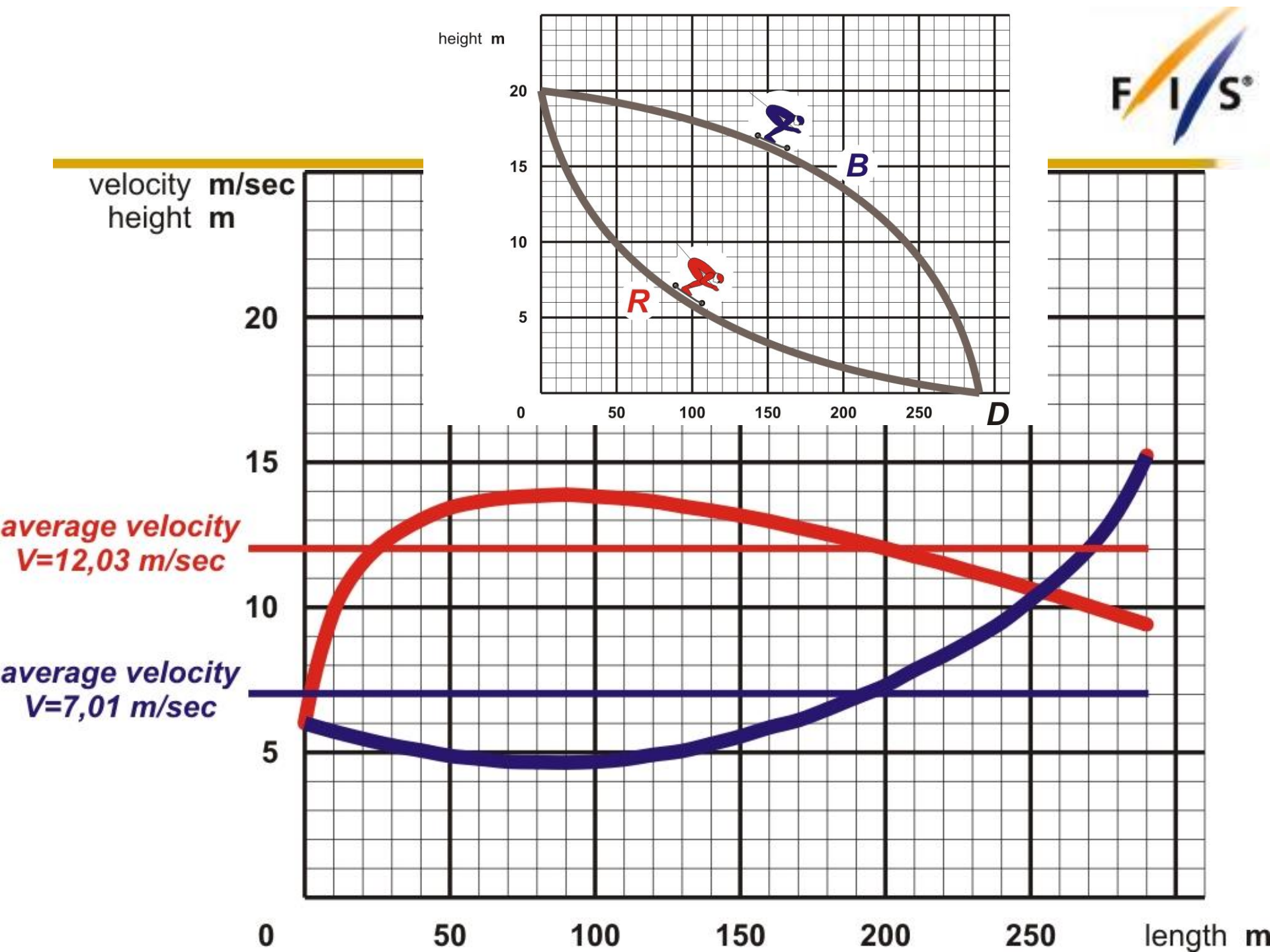
The answers:

1. Red athlete will arrive to D point earlier

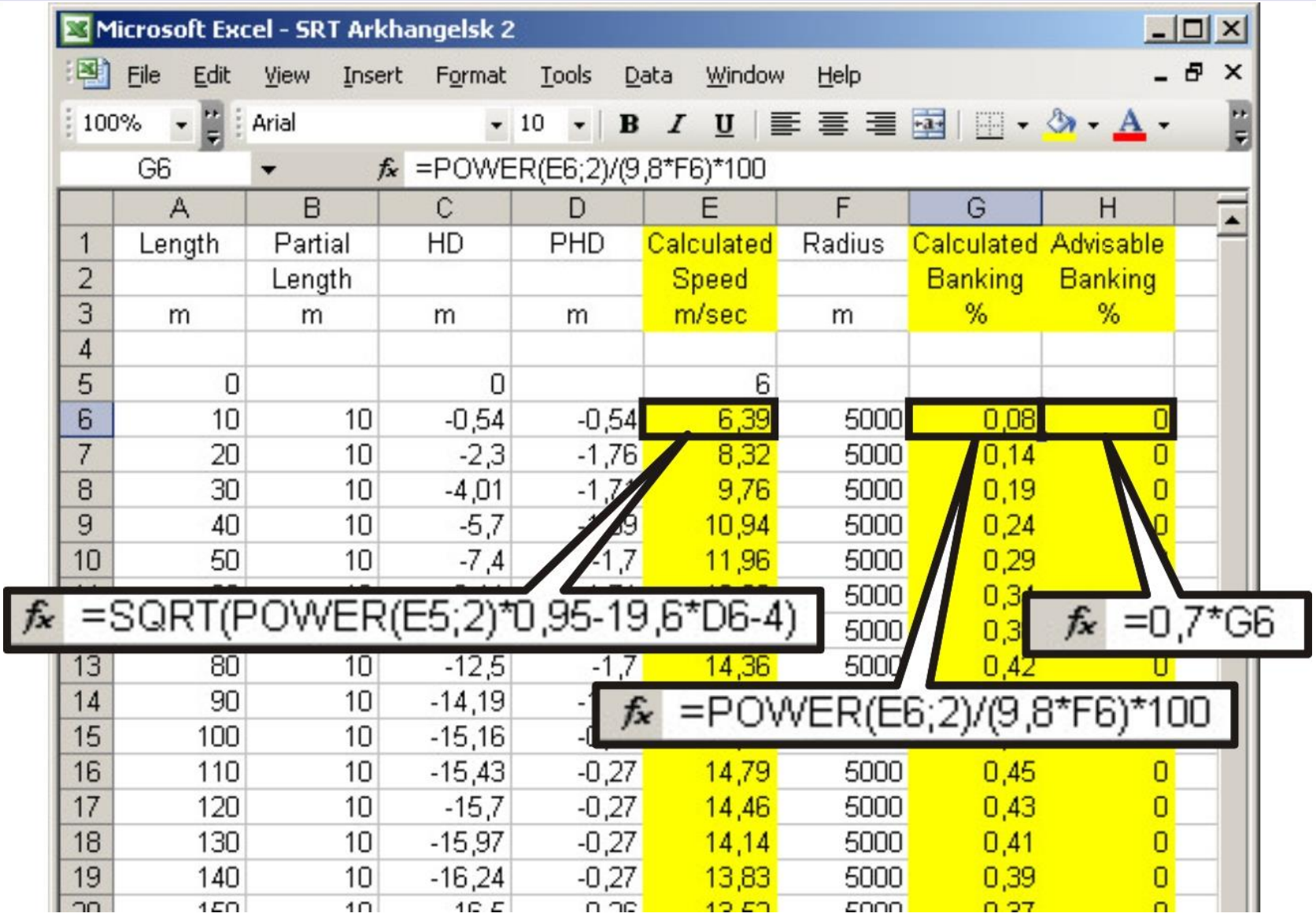
Velocity of Red athletes will be less than one of Blue athlete in D point

Red kind of downhill is much more preferable for roller course. The steep initial part of down hill makes athlete to reach high speed quickly. On the second part of down hill athlete's speed declines and safe turning becomes possible.

The RED kind of downhill is much preferable for roller course


height m
20
15
10
5
0
50
100
150
200
250
D
B
R
velocity m/sec
height m
20
15
10
5
average velocity
V=12,03 m/sec
average velocity
V=7,01 m/sec
0
50
100
150
200
250
length m

Returning to our formula (slide 9):
Now we can develop our previous EXCEL form to get a calculated and advisable angle of banking.

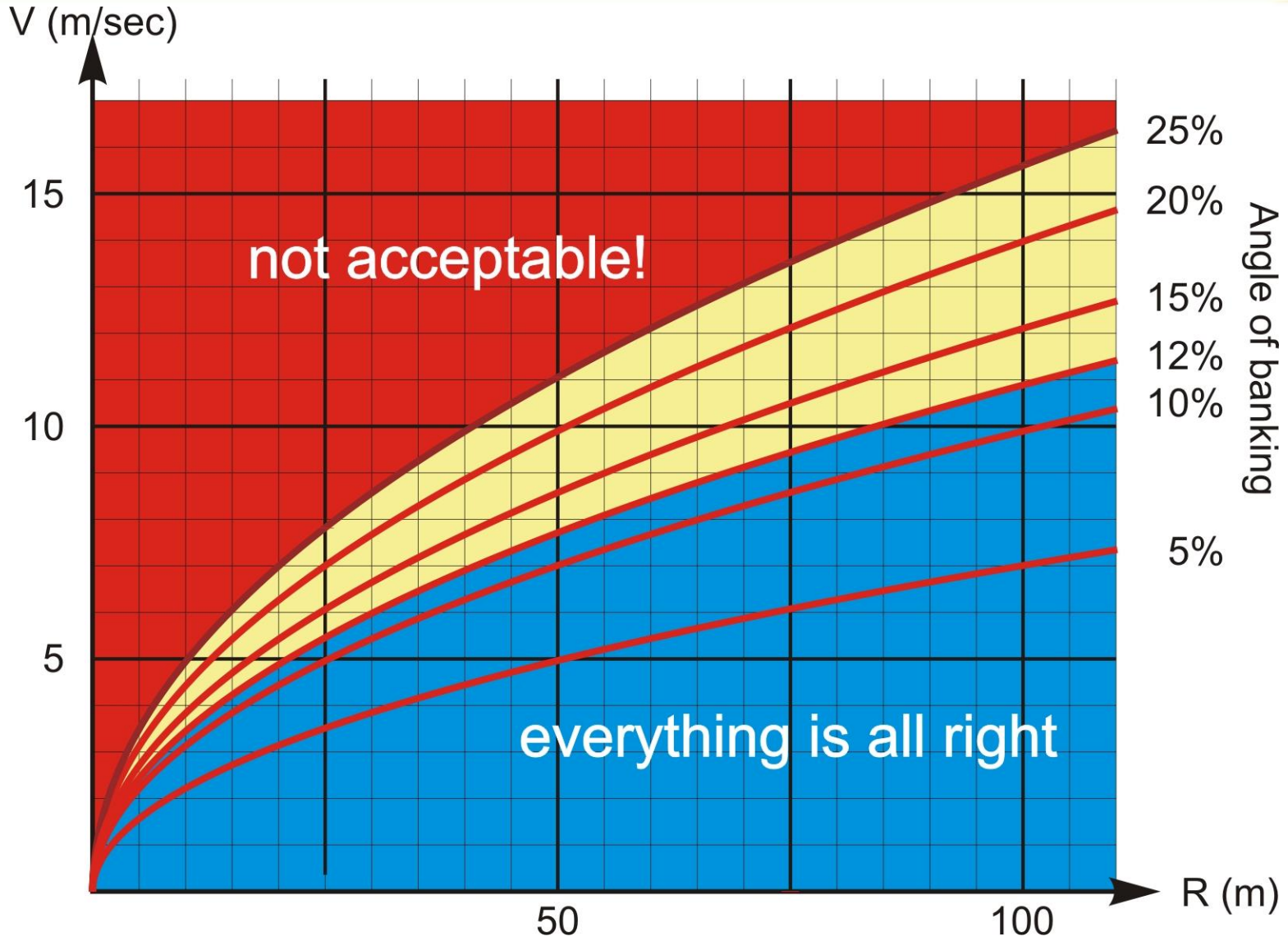


	A	B	C	D	E	F	G	H
1	Length	Partial	HD	PHD	Calculated	Radius	Calculated	Advisable
2		Length			Speed		Banking	Banking
3	m	m	m	m	m/sec	m	%	%
4								
5	0		0		6			
6	10	10	-0,54	-0,54	6,39	5000	0,08	0
7	20	10	-2,3	-1,76	8,32	5000	0,14	0
8	30	10	-4,01	-1,7	9,76	5000	0,19	0
9	40	10	-5,7	-1,69	10,94	5000	0,24	0
10	50	10	-7,4	-1,7	11,96	5000	0,29	
11						5000	0,3	
12						5000	0,3	
13	80	10	-12,5	-1,7	14,36	5000	0,42	0
14	90	10	-14,19	-1				
15	100	10	-15,16	-0				
16	110	10	-15,43	-0,27	14,79	5000	0,45	0
17	120	10	-15,7	-0,27	14,46	5000	0,43	0
18	130	10	-15,97	-0,27	14,14	5000	0,41	0
19	140	10	-16,24	-0,27	13,83	5000	0,39	0
20	150	10	-16,5	-0,26	13,52	5000	0,37	0

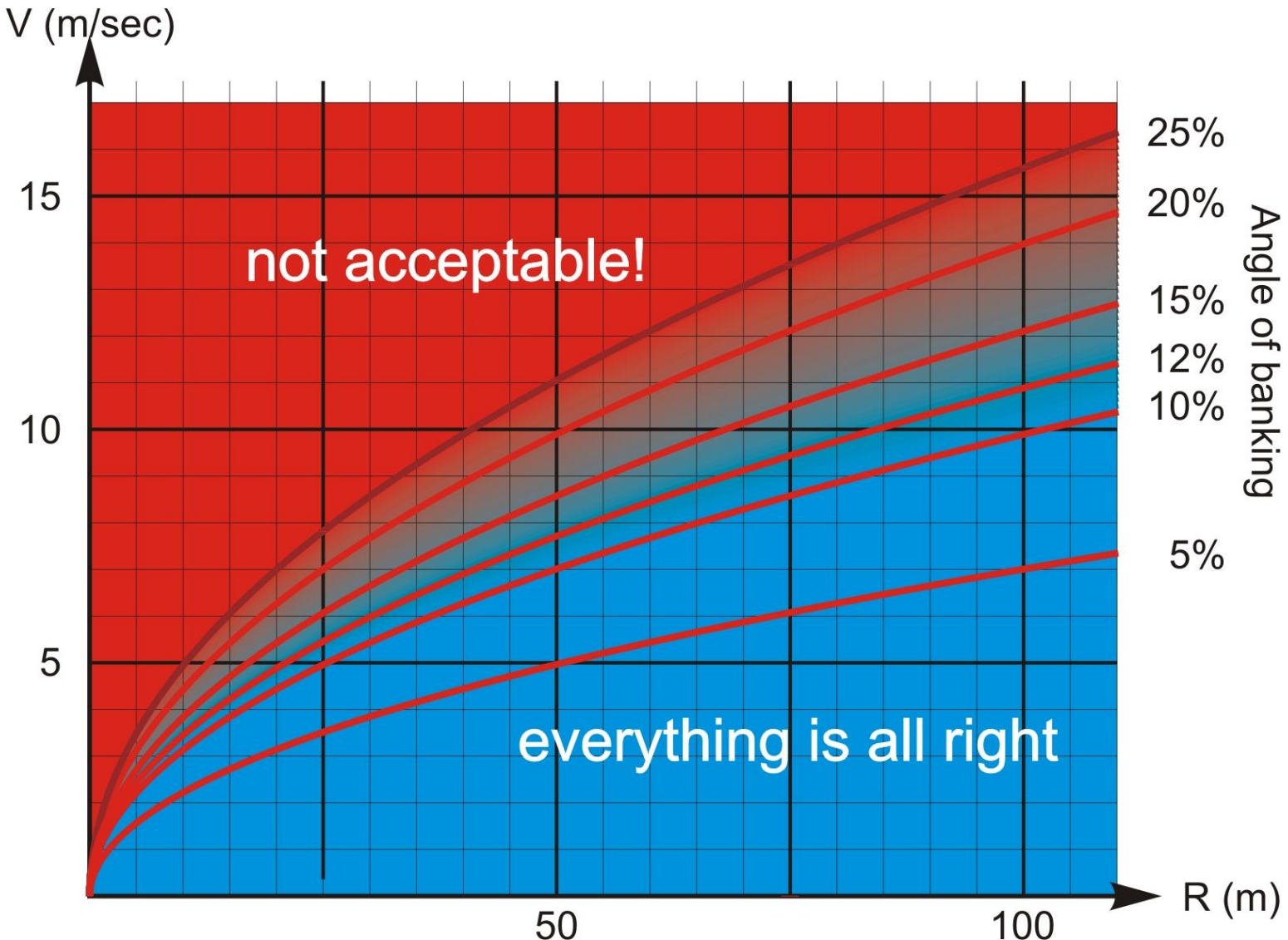
Which value of curve banking angle is acceptable?

- From empirical experience banking less than 12% angle is easily created by means of usual road building machinery.
- Athletes can pass easily such curves, so the zone 12% and less should be considered as an acceptable one.
- In some rollerski course there are curves with 25% banking angle. The zone with more than 25% is absolutely unacceptable.
- What about zone between 12 and 25% (yellow zone)?

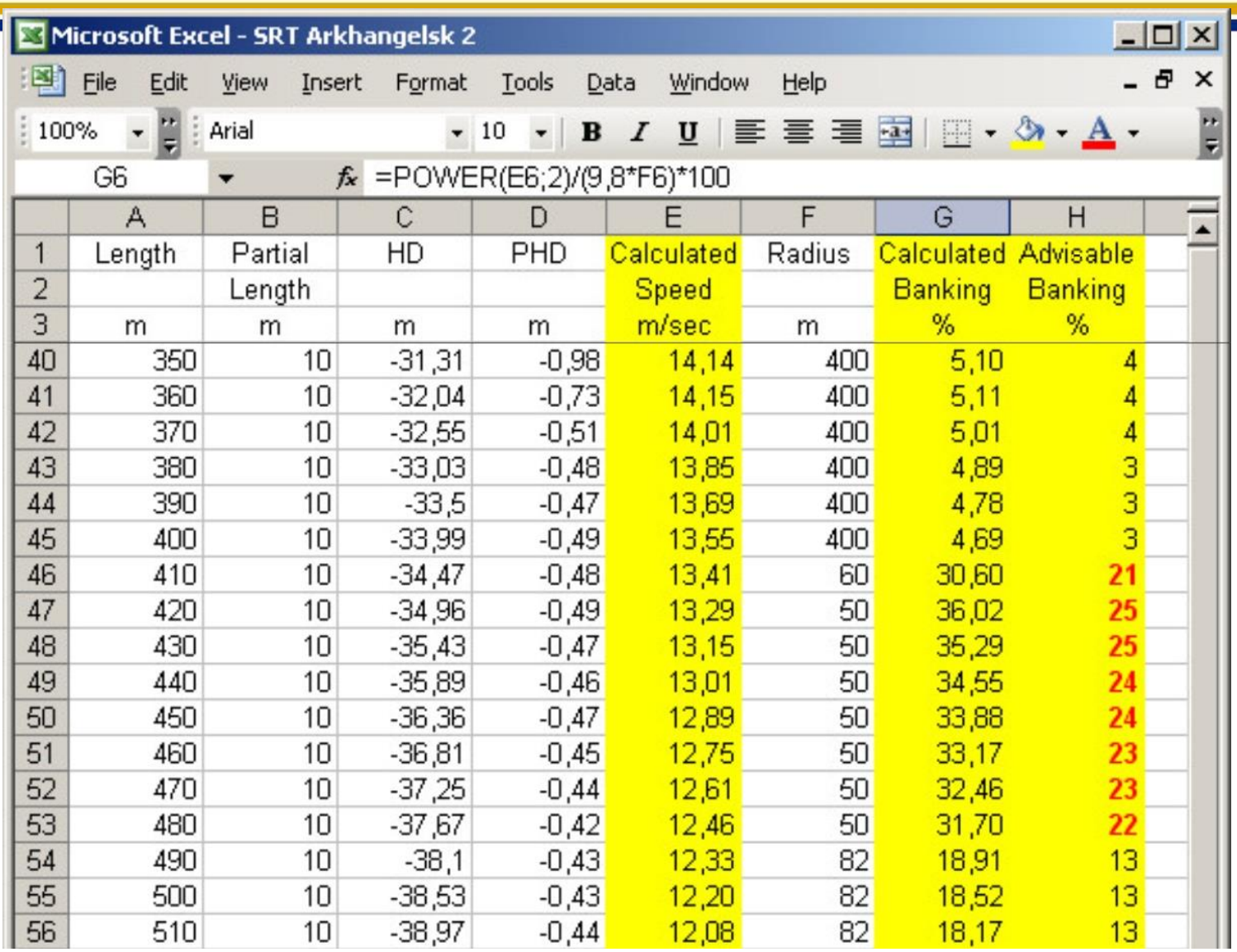
Banking angle of rollerski course curves



There is no clear border between YES and NO. It depends on safety standards, athletes' skills level, possibilities of designers and constructors etc.
So it'll be more correct to redraw this picture:



For example in Arkhangelsk region (RUS) 20% limit for banking was accepted. Final off limit figures are set off in red.



Microsoft Excel - SRT Arkhangelsk 2

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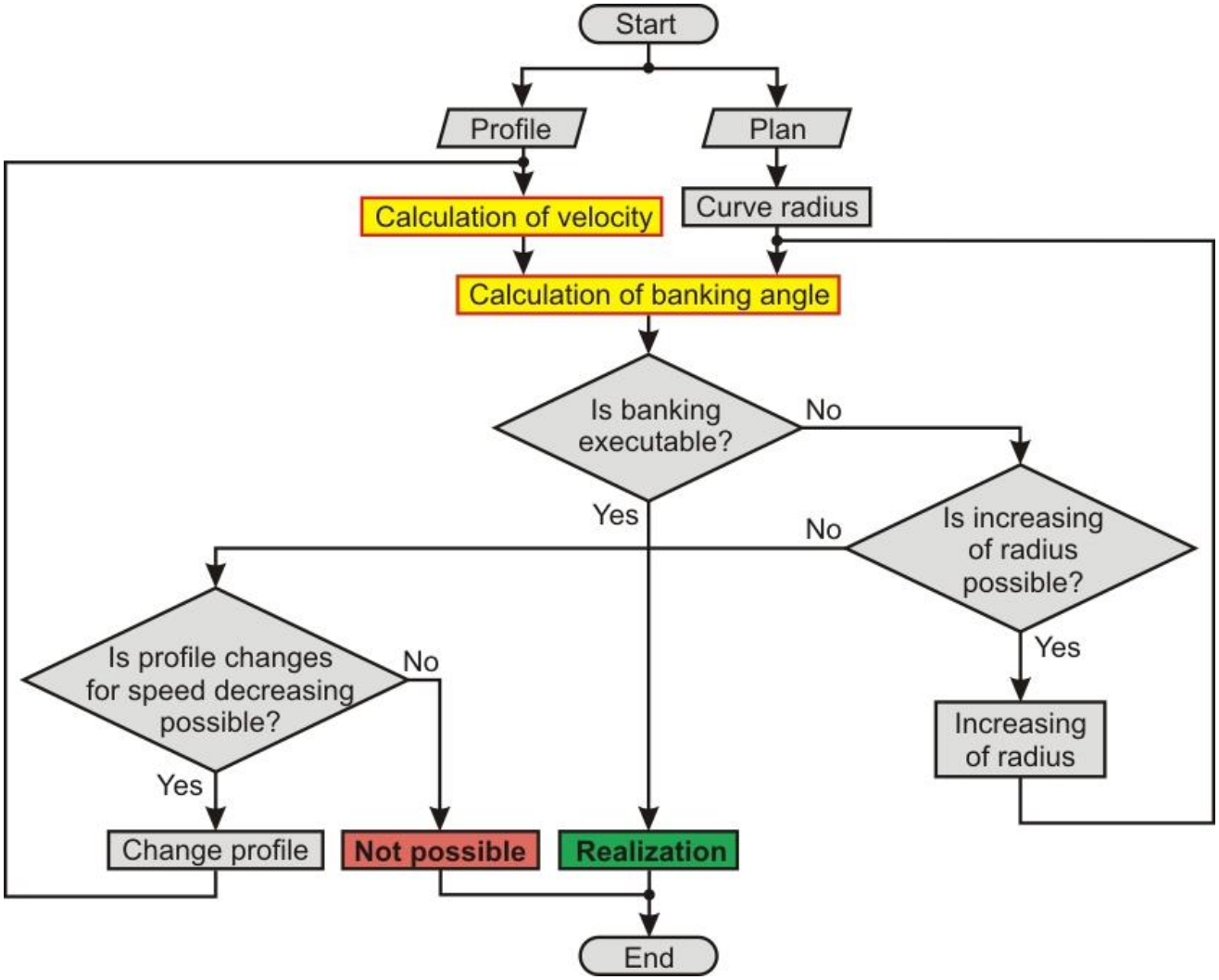
100% Arial 10 B I U

G6 =POWER(E6;2)/(9,8*F6)*100

	A	B	C	D	E	F	G	H
1	Length	Partial	HD	PHD	Calculated	Radius	Calculated	Advisable
2		Length			Speed		Banking	Banking
3	m	m	m	m	m/sec	m	%	%
40	350	10	-31,31	-0,98	14,14	400	5,10	4
41	360	10	-32,04	-0,73	14,15	400	5,11	4
42	370	10	-32,55	-0,51	14,01	400	5,01	4
43	380	10	-33,03	-0,48	13,85	400	4,89	3
44	390	10	-33,5	-0,47	13,69	400	4,78	3
45	400	10	-33,99	-0,49	13,55	400	4,69	3
46	410	10	-34,47	-0,48	13,41	60	30,60	21
47	420	10	-34,96	-0,49	13,29	50	36,02	25
48	430	10	-35,43	-0,47	13,15	50	35,29	25
49	440	10	-35,89	-0,46	13,01	50	34,55	24
50	450	10	-36,36	-0,47	12,89	50	33,88	24
51	460	10	-36,81	-0,45	12,75	50	33,17	23
52	470	10	-37,25	-0,44	12,61	50	32,46	23
53	480	10	-37,67	-0,42	12,46	50	31,70	22
54	490	10	-38,1	-0,43	12,33	82	18,91	13
55	500	10	-38,53	-0,43	12,20	82	18,52	13
56	510	10	-38,97	-0,44	12,08	82	18,17	13

What should we do if we get off limit figures? Here is the algorithm of curve designing.



Explanation of decision chart

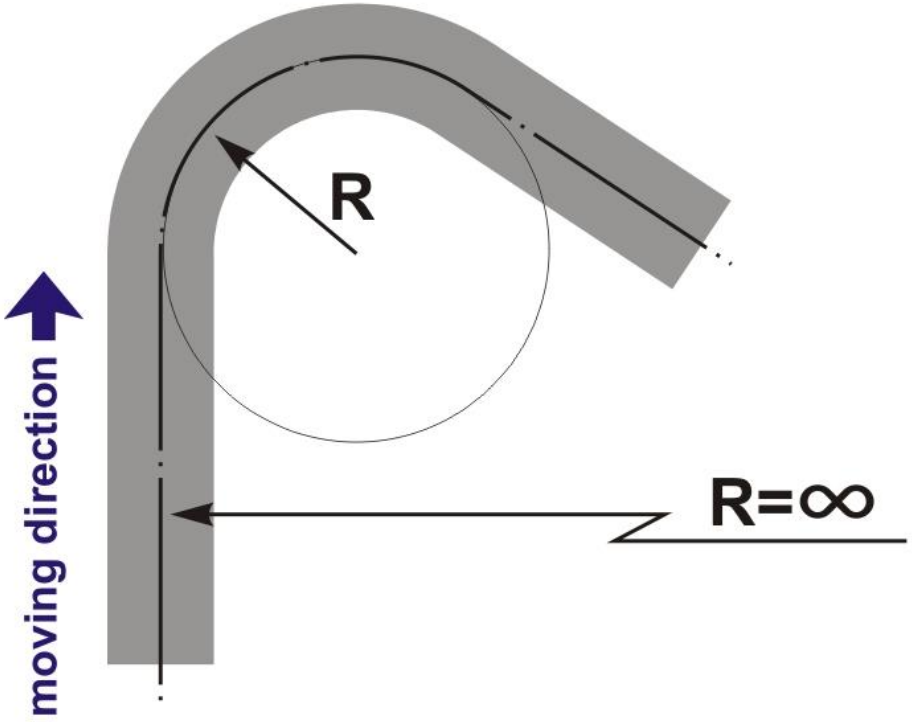
- Initial information is the plan of the course (course) and profile of downhill.
- Using profile data calculate athlete’s velocity at the beginning of curve.
- Knowing velocity and radius we can calculate banking angle.
- If banking isn’t acceptable we increase radius or decrease velocity by means of profile changing.
- course heigh profile changing is connected with earth works and it is very costly. So it should be considered as a last measure.

•But sometimes profile changing is the only way to provide suitable passing conditions.

•Two artificial hills were made in Demino Rybinsk.

SMOOTH & SAFE CURVE DESIGN IN ROLLERSKI course

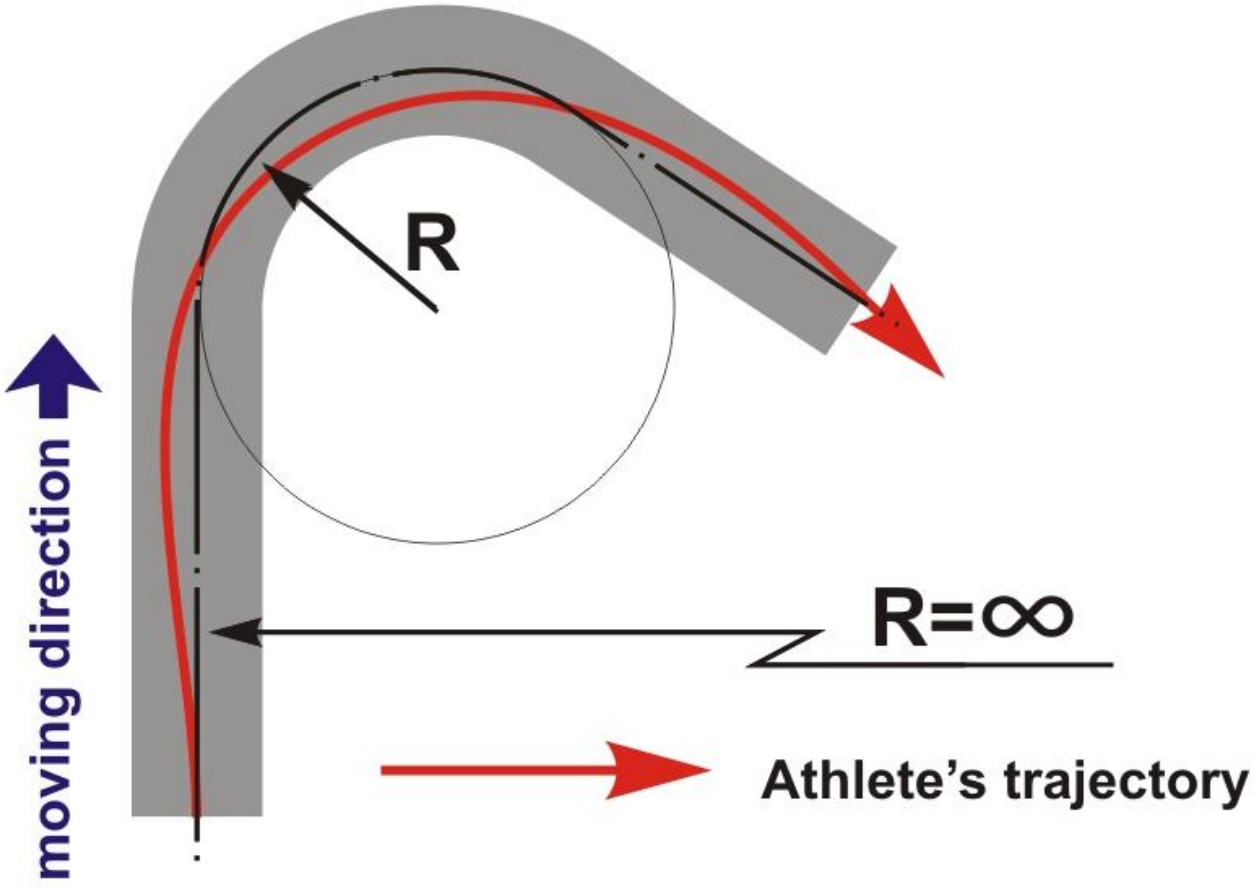
SOME MORE ISSUE OF ROLLER course CURVE DESIGN



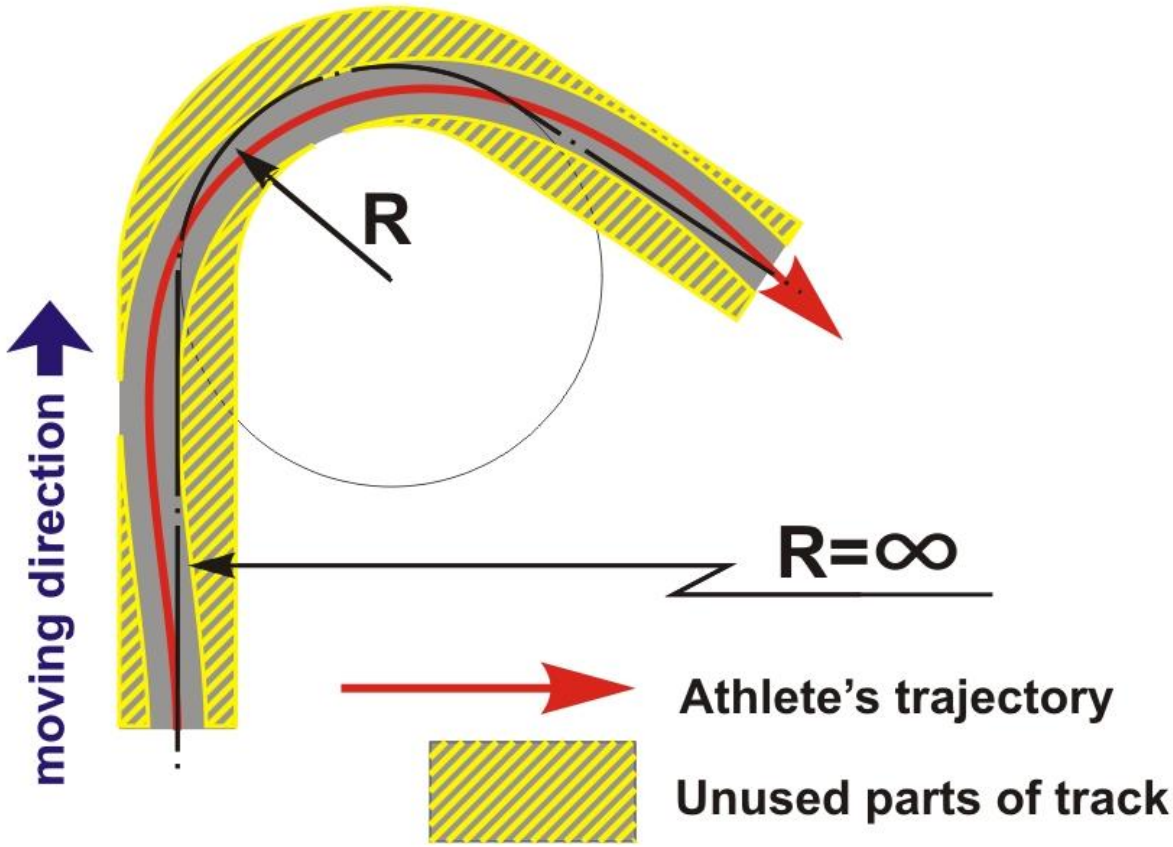
Athlete moves in a straight line, then begins movement on curve with radius R. But athlete can’t change his inclinination so fast..

Curve design

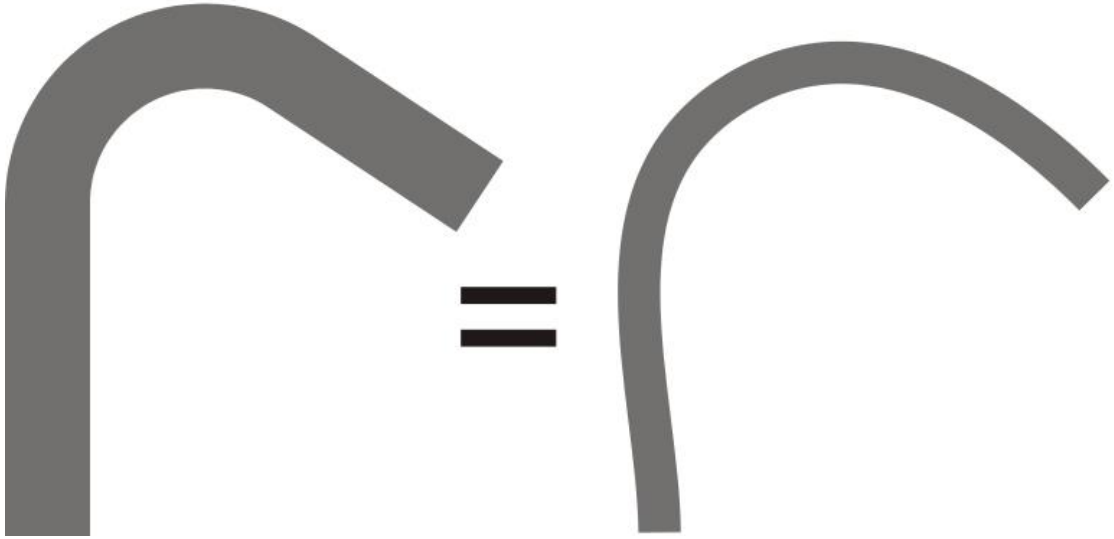
- The centripetal force and the radius can’t change in so easily.
- The athlete won’t follow the axial of the course but only his own trajectory.



- So some unusable parts of course surface appear
- Only narrow strip can be used



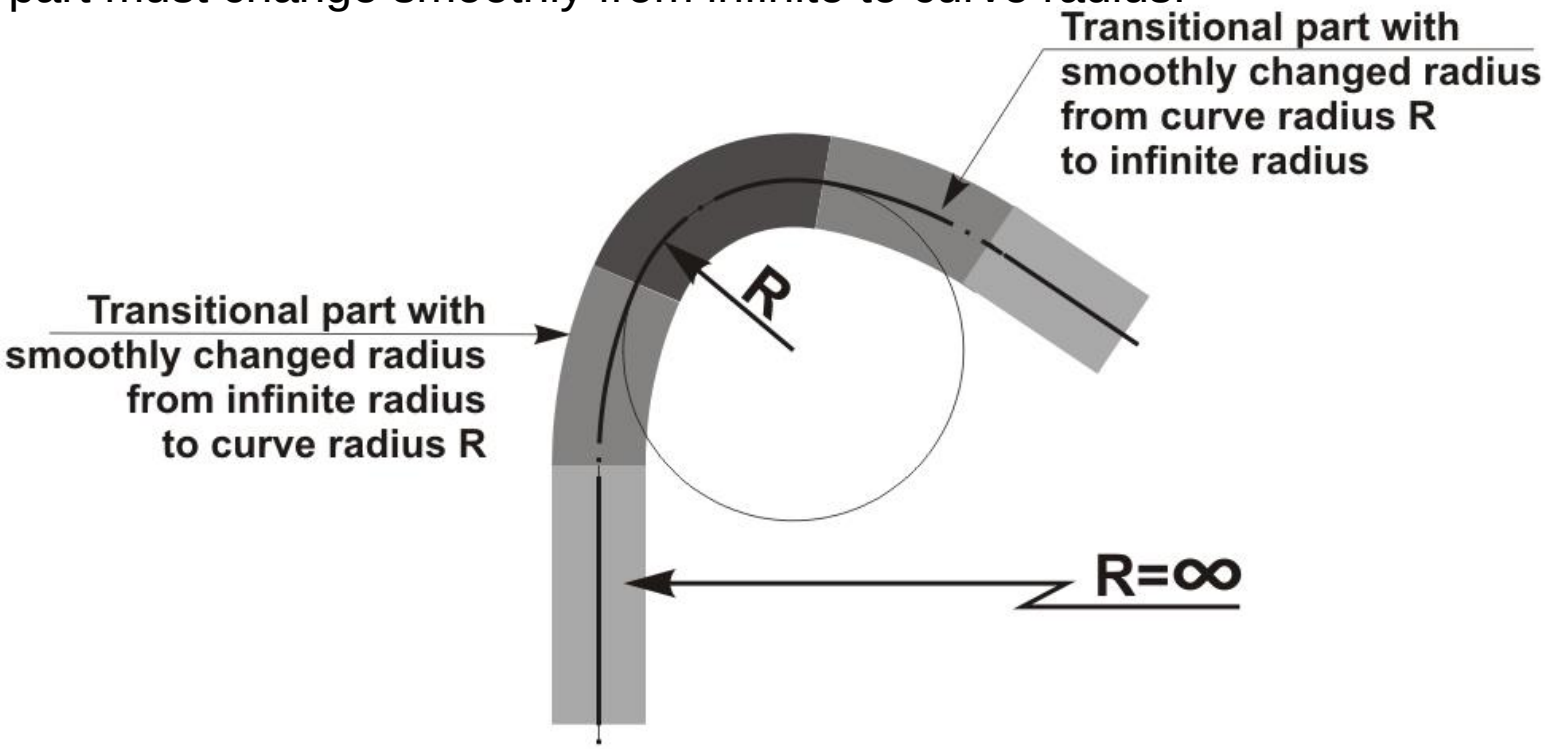
CONSEQUENCES OF IDEAL TRAJECTORY



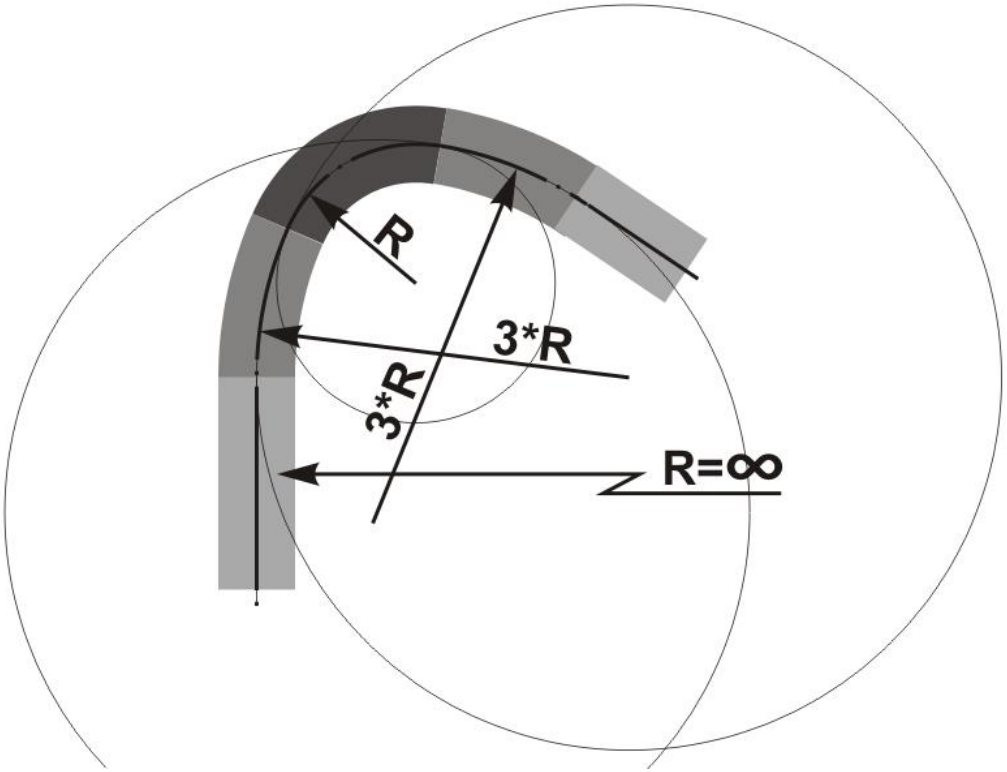
There is no sense to have local narrowing. It reduces carrying capacity of whole course. The unusable areas of course surface mean waste of money. So what should we do?

Curve design

To avoid this phenomenon we should make axial line of course closer to athlete's trajectory (ideal line). Good way to do it is to arrange transitional part between straight line (infinite radius) and curve part. The radius of curvature of this part must change smoothly from infinite to curve radius.

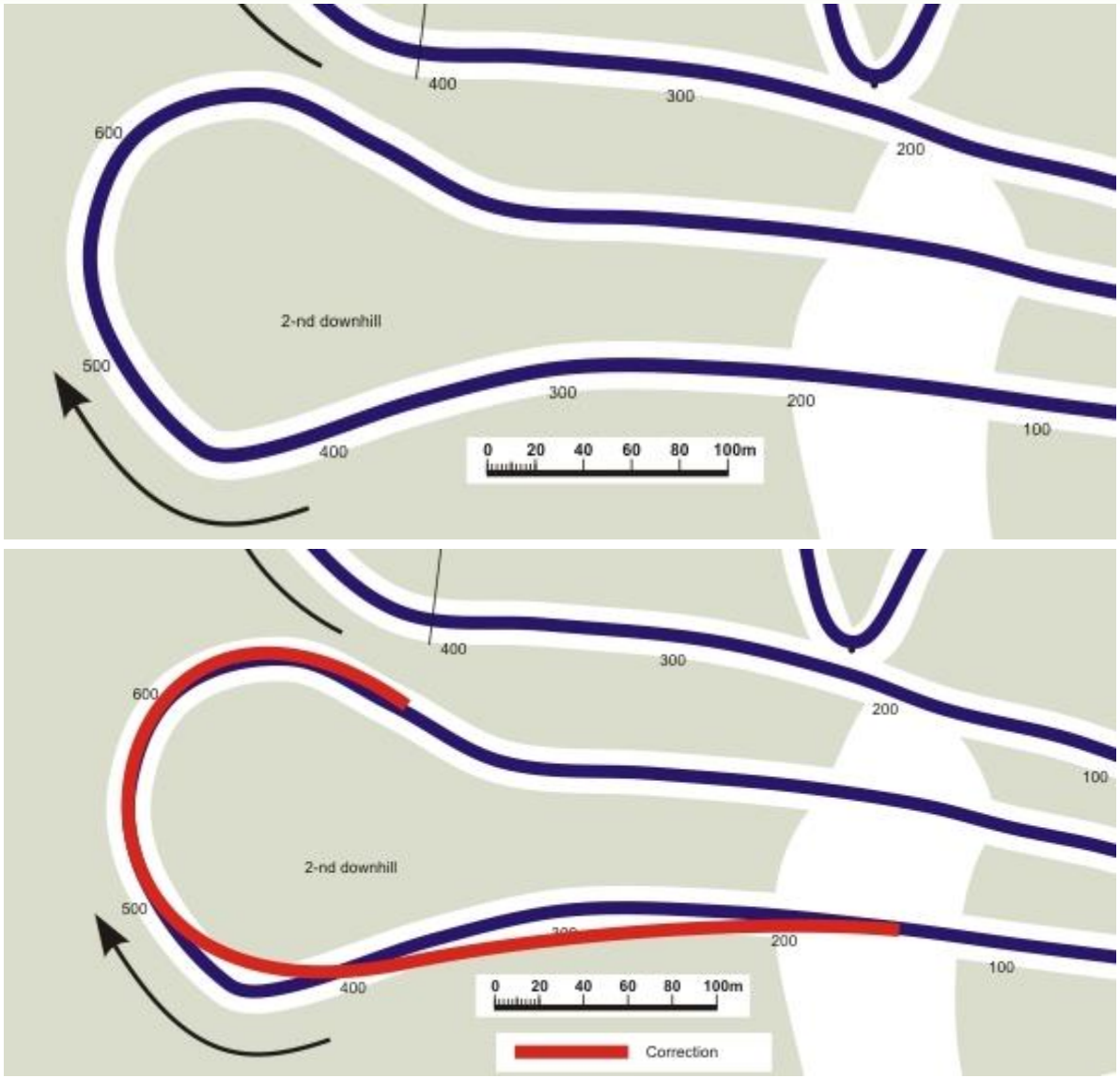


Another way (and more simple) is to make transitional part with triple curve radius. Length of transitional part must not be less than 10-fold width of course.

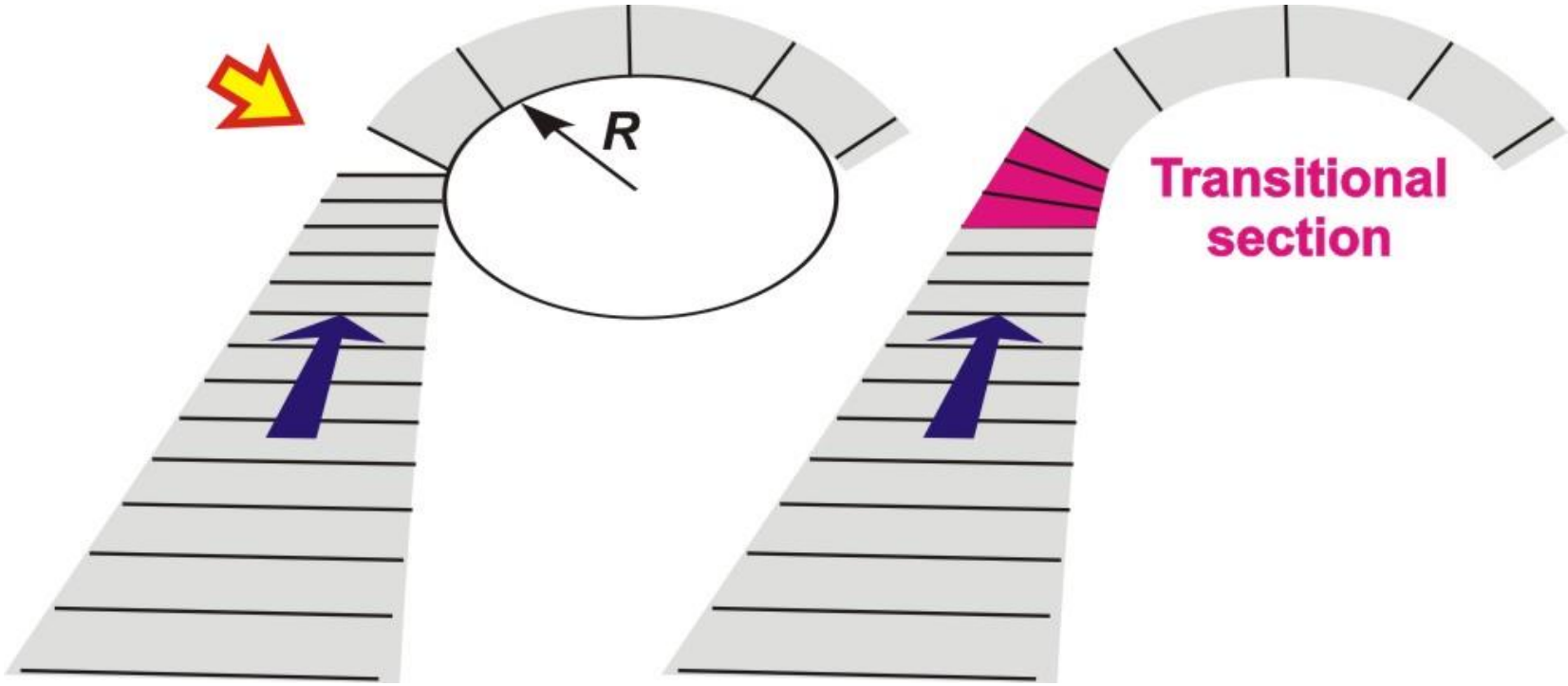


This issue is especially important if radius is less than 10-fold width of course

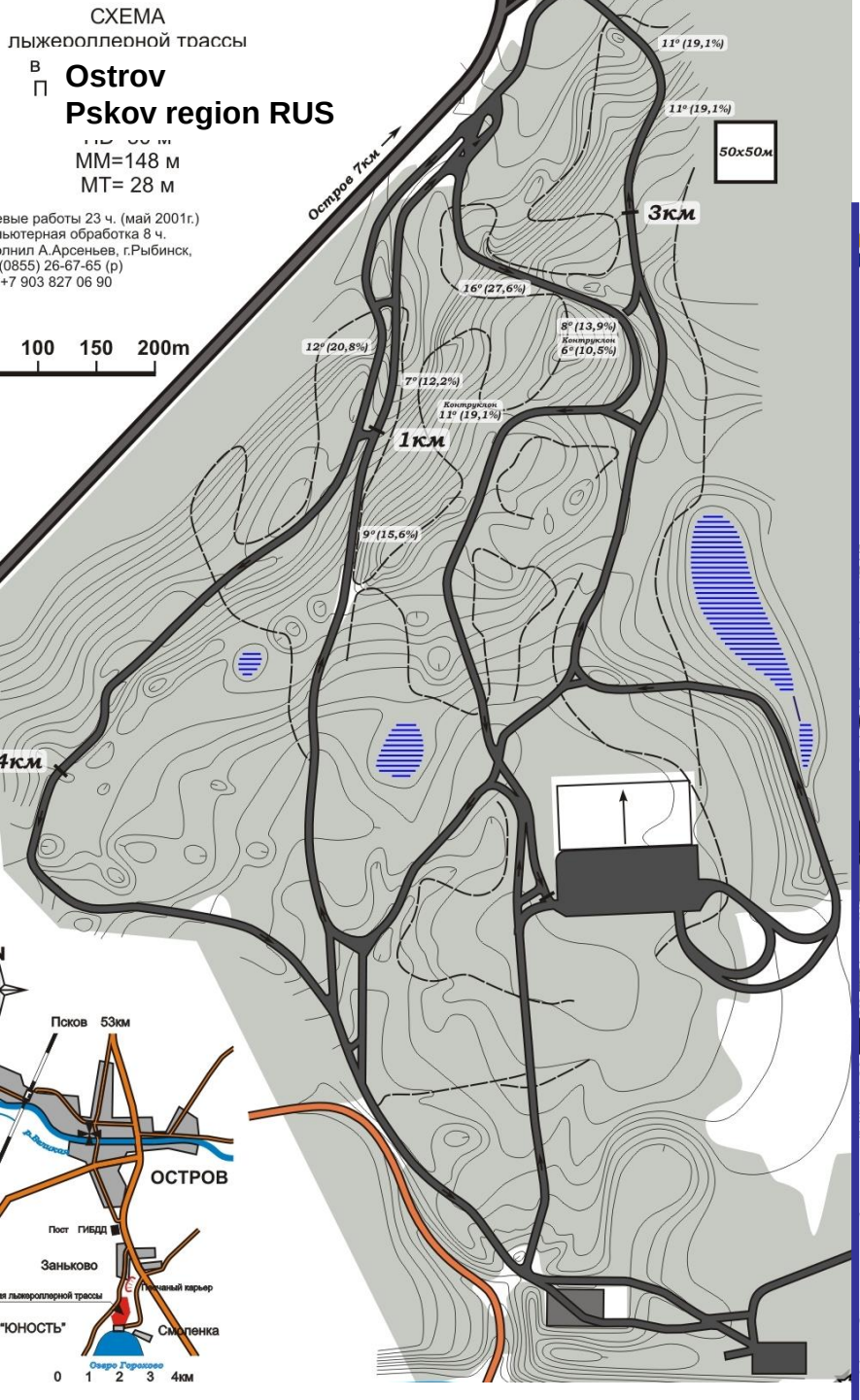
The common rule concerning high speed sections is: All changes of curve radius should be executed as smooth as possible.



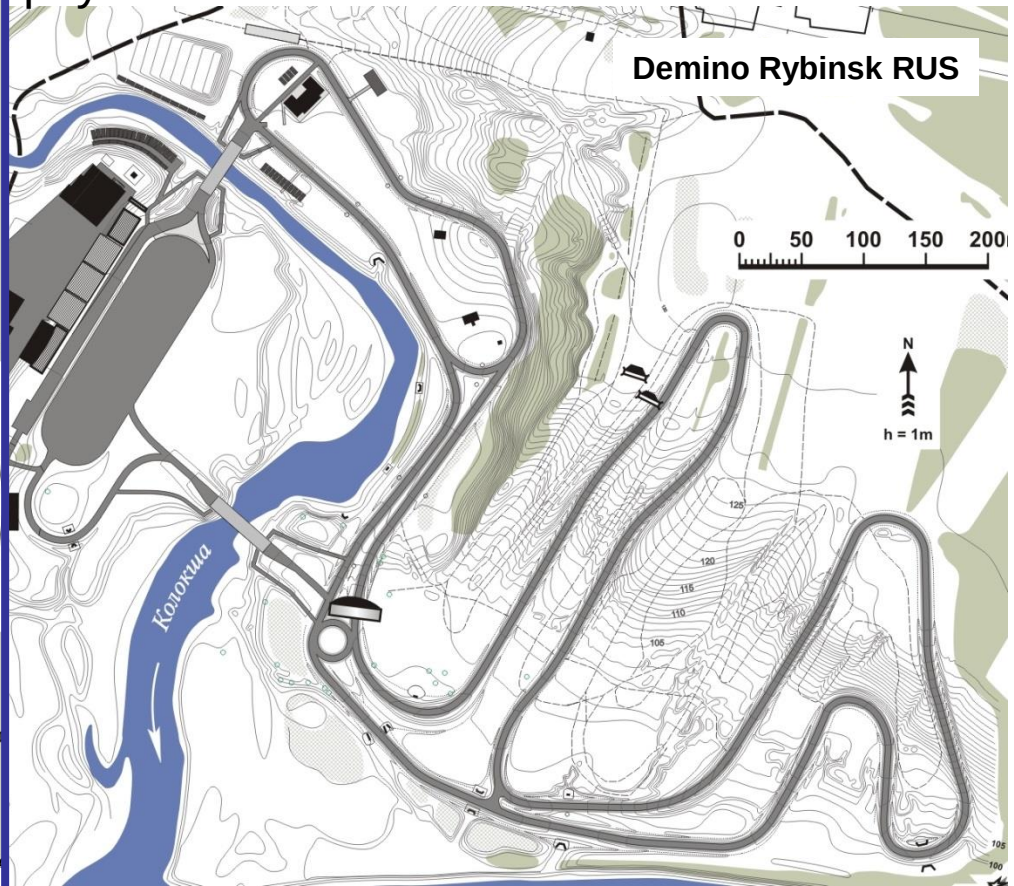
Curve banking angle



- Curve banking angle can’t change in a flash.
- Rate of curve angle change should not be more than 0,5% per running meter.



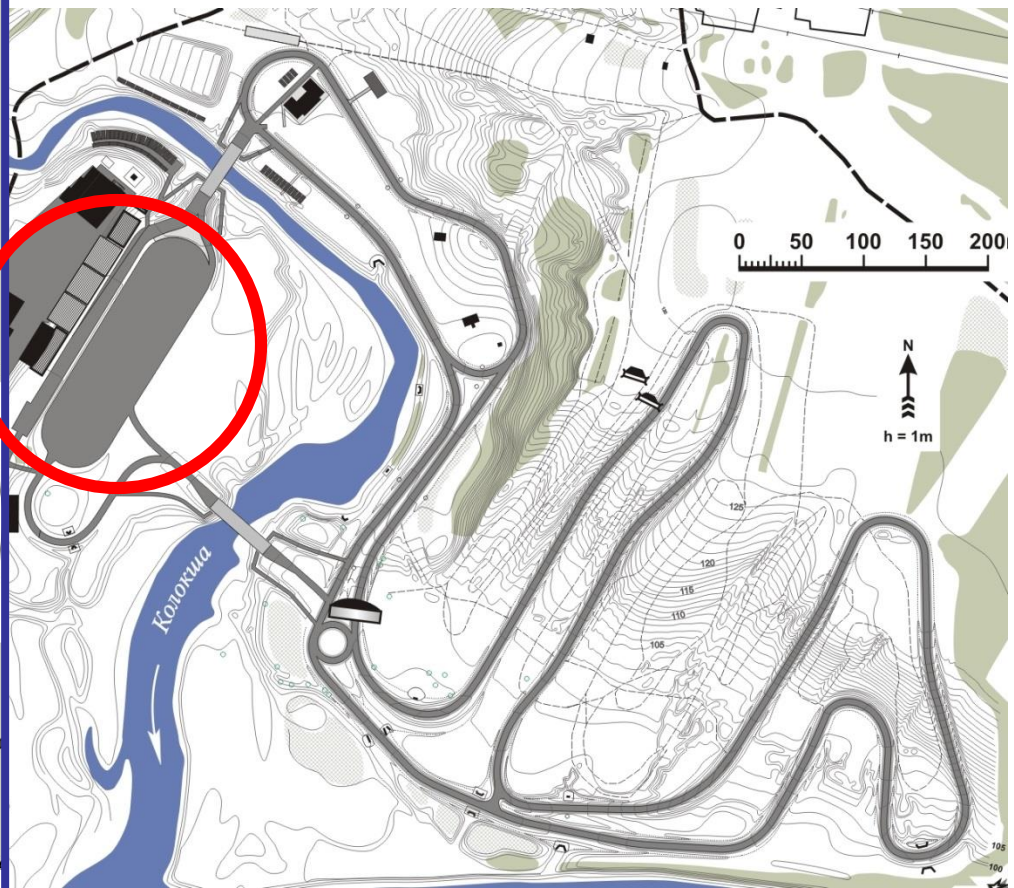
Roller course should consist of parts of different complexity degree. They should be connected with each other by means of cut-off sections to create routes for any level of physical exercise



Ostrov
Pskov region RUS

Asphalt covered area should be joined to course to organize start/finish/other zones if needed (to be able to carry out competition)

Demino Rybinsk RUS

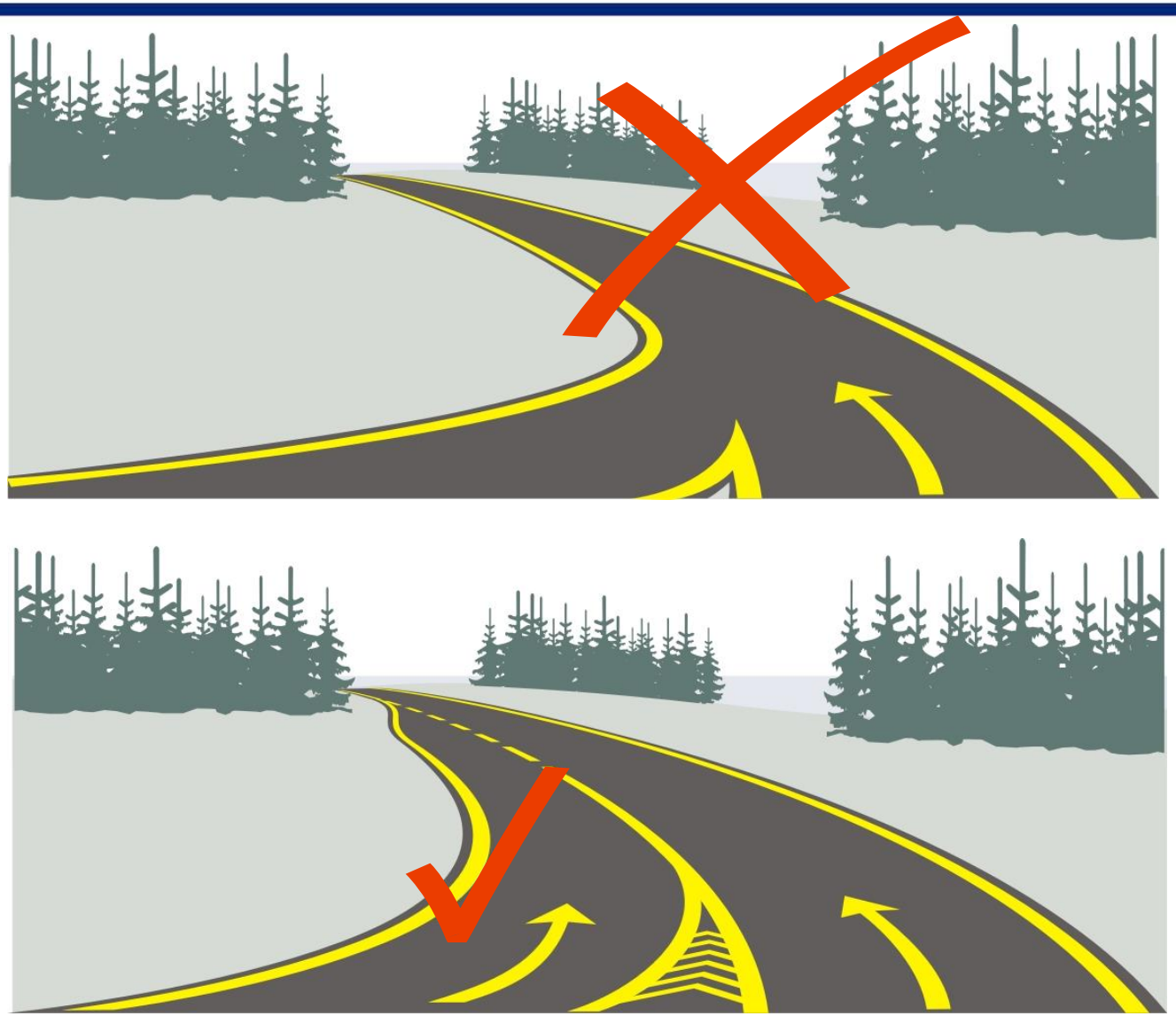


SOME SAFETY ASPECTS & COURSE DESIGN GUIDELINES

Marking of moving directions

It’s extremely important to inform athletes about permitted moving direction. The easy visible arrows which are marked right on asphalt is the best way for this purpose. But they shouldn’t be too big to don’t make worse asphalt friction

All junctions must be designed in places with low expected athletes' velocity



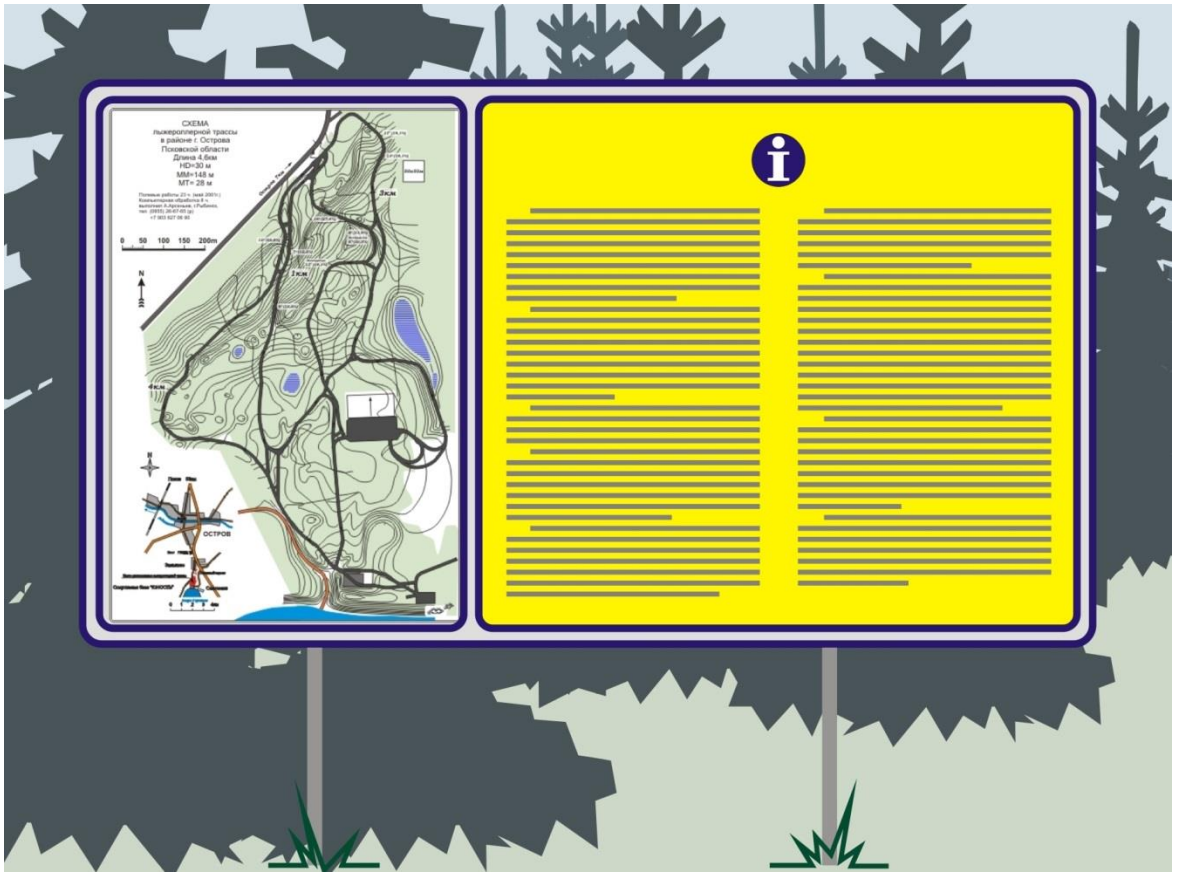
GENERAL SAFETY GUIDELINES FOR ROLLERSKI COURSE DESIGN

- The consequences of falling on rollerski course are much more serious than ones on ski course.
- All potentially dangerous obstacles like trees, stumps, stones and so on must be removed from adjacent areas.
- The grass cover is very desirable for this stripe.
- Gravel or crash stone are absolutely inadmissible along the apshalt sides
- Outer part of curves must have more free «roll out» area than inside one.

EXAMPLES INFORMATION SIGNS ALONG THE ROLLERSKI COURSE

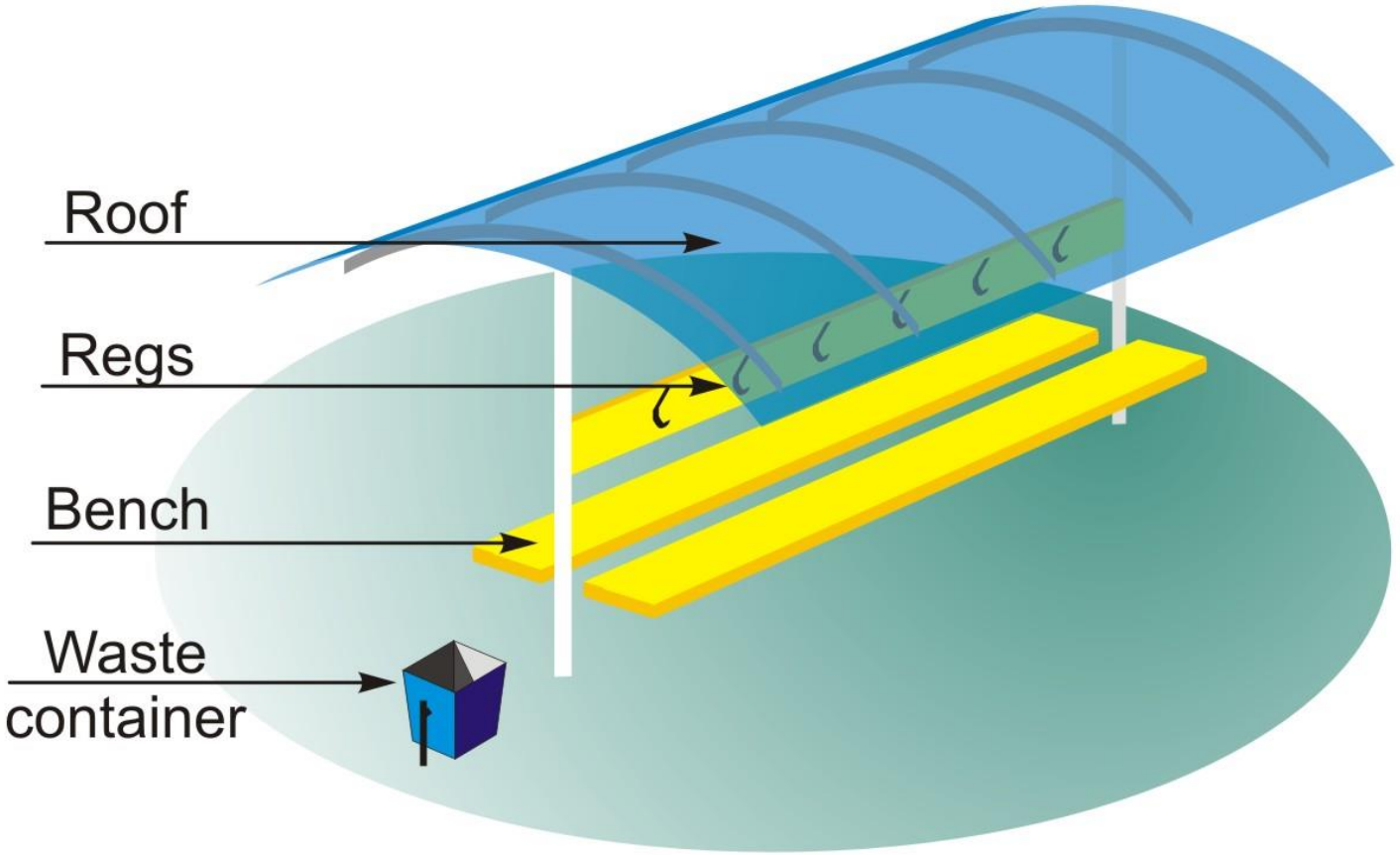
•The information board has to be installed near the beginning of the course.

•Following information should be published on the board:

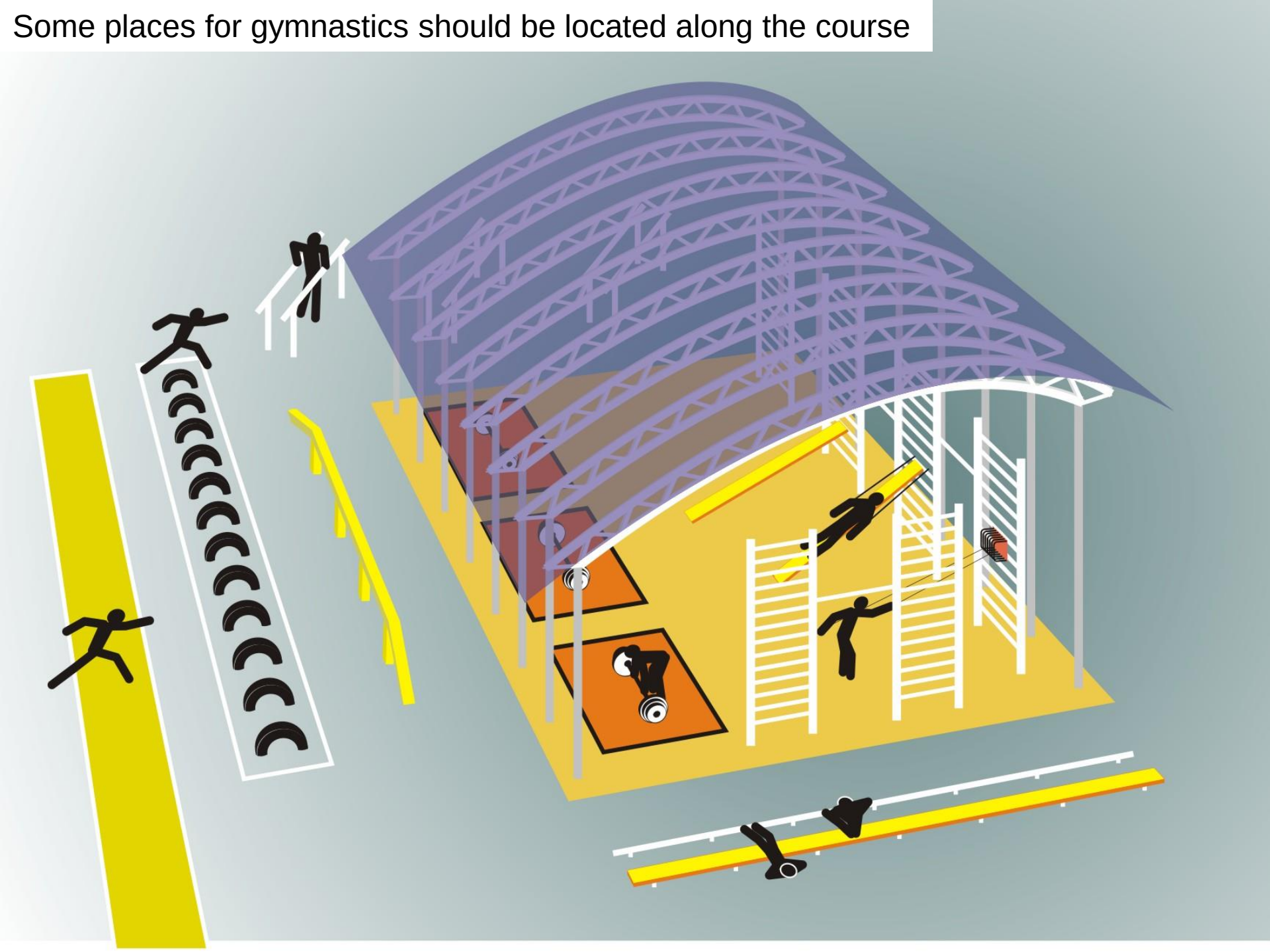


- Map of course
- Typical routs
- Obligatory moving direction
- Height parameters
- Level of difficulty
- Opening/closing time
- Means of athletes' protection
- Restrictions of course using
- (weather and others).

CREATION OF SIMPLE SHELTERS ALONG THE course



Some places for gymnastics should be located along the course



This informative material is created with help of Andrey Arsenyev, (RUS)