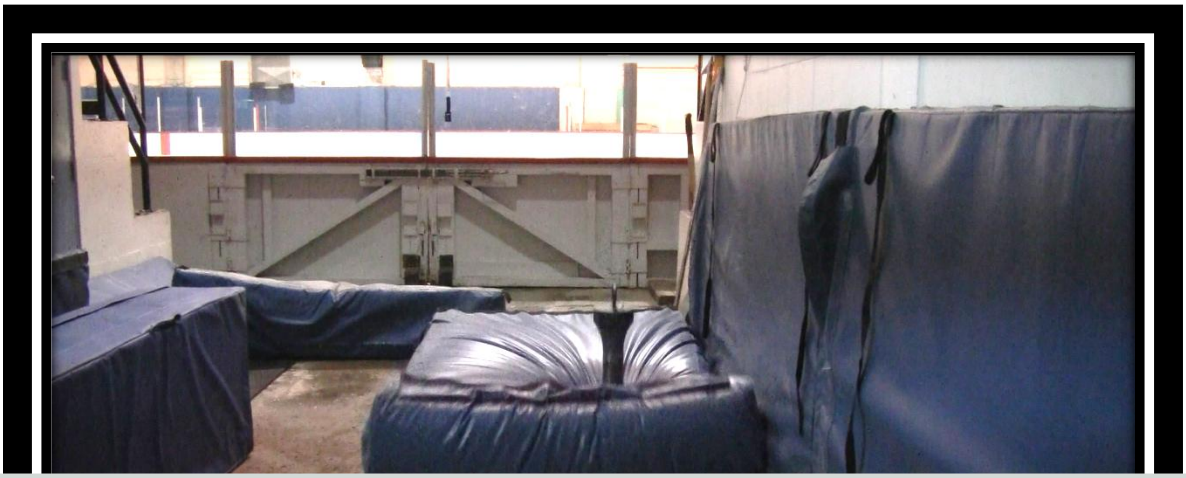

Analysis on crash pad protection for short track on boarded rinks

Analysis and recommendations

SPEED SKATING CANADA

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Analysis on crash pad protection for short track on boarded rinks

ANALYSIS AND RECOMMENDATIONS

EXECUTIVE SUMMARY

In the last few years, many injury happen in short track skating. The purpose of this analysis was to compare different configuration of mats to the ISU (International Skating Union) requirement and to develop solution for clubs in Canada to improve the safety of their skaters.

The testing used to evaluate different protection look at G force values during impact. The G force is not a force but a measure of a sudden deceleration for a skater going into the mats. The impact is measured by an accelerometer. The G force acting on a skater during the impact is characterized by the peak deceleration as a multiple of his body weight.

The ISU requirement and protocol can be found in ISU communication 1512. The ISU requirement impact values in G force need to be lower or equal to 7.9G, 12.8G, 17.3G and 21.5G force at respectively 1-2-3 and 4m drop of a solid object of 32kg with a circular surface contact of 20cm of diameter.

Testing was done on different mats clubs from 20cm to 30cm of thickness and some combination of those mats. Results show a lot of variability between all those mats which is probably characterise the reality in the current clubs in Canada.

None of those mats or combination of those mats meets the ISU requirement except the combination of two mats of 30cm that equal the requirement. The fact that most of the clubs mats do not match the ISU requirement explains part of those injuries. As an example, a single 30cm of padding can be 60% off the ISU the requirement at 4m and 25 % off at 2m.

More testing was done with different configuration of padding to find and develop a system that will meet the ISU requirement. A short soft mat (Figure 1) of 60cm height, 35cm deep and 225cm long place behind the current clubs mats in the turn showed very consistent low G force values to surpass the ISU requirement by 28%.

FIGURE 1 SHORT MATS QC

The conclusion of this analysis on current clubs crash pads is to be expected, clubs need to have more than 20cm, 30cm or the combination of 2x20cm of padding to improve safety of their skaters and be within the ISU requirement. The configuration with the additional soft short mats behind current mats is very interesting for clubs since the performance is great with whatever mats they currently use. It's also a cost efficient to get those additional mats to surpass the ISU requirement by around 28% to better protect their skaters without having to replace all their current mats.

Content

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(In alphabetic order):

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- Sebastien Rioux

Those persons help in many ways within their own expertise and experience in the sport and they have made this project possible.

INTRODUCTION

Injury in Short Track is currently high on boarded rink. In the province of Quebec in the last two years (2009-2011) from the total of 281 injuries recorded, 35 concussion and 30 fractures had occur. This situation has been similar for several years now. With high risk of injuries many skater are scare to go fast, some choice to skate long track, some quit the sport.

Those numbers force to analyse the current situation and develop simple solutions that will improve the protection of the skaters. The impact in the mats generate a lot of G force; depending mainly by the mats system and the skaters speed and his body mass. Since the body mass is not really a variable and the speed of the skater is what they want to improve, it become evident that the best solution is to look at the mats system.

The mats system can then be improved to generate a lower peak of deceleration for the skater by reducing the speed of the deceleration. That can be done by increasing the time and the distance that the skater has to stop in the mats.

One of the problems is that the speed and the masse of every skater are not the same, the mats system cannot be ideal for each of them. For example, for a given mats, if the skater is too heavy and fast, he will carry a lot of energy and it will take him no time to squeeze the mats, he will bottoming out so the G force will be high because the deceleration happen to quickly. If the mats are too stiff, the skater will not be able to squeeze those mats and the distance will be too short so the G force will be high because the deceleration happen too quickly again. The challenge is to find a system that will provide time and distance to stop the skater so that the deceleration doesn't happen too quickly.

One of the best solutions is to remove the boards, that provide more time and more distance for the skater to stop because the mats move more or less with the skater depending of the energy he has at the impact. That's make the system efficient for basically all the different level of energy the skaters has, resulting in a low G force impact because most of the energy have been absorb by the moving system and not only by the mats itself. The deceleration doesn't happen too quickly, the system provide more time and distance to stop the skater.

The best option with boarded rink is to look for a similar idea than the board less system. Basically to setup the mats to provide more time and distance to get a deceleration has continuous as possible.

To reach that goal, many questions have been answered by testing many different configurations of mats. Those questions are:

1. What is the variability of the testing with the ISU protocol?
2. How current mats score compare to ISU recommendation?
3. What is the score by adding more mats at 4m?
4. What is the score by adding more mats at 2m?
5. What are the shape and the behaviour of those additional mats?
6. How stiff the additional mats has to be?
7. Where to place the additional mats in front, in the middle or at the back, by the board?
8. What is the influence of having the front mats attach to each other?

To be able to answer those questions we had to evaluate the current mats. The ISU protocol has been chosen since it's the reference base to be able to compare any mats system. The ISU protocol has some limits and advantage. The main limits are the specificity of the test; it's not specific in term of weight, form and speed. The main advantages are that it's easy to do, and it's give a standard way to compare mats around the world.

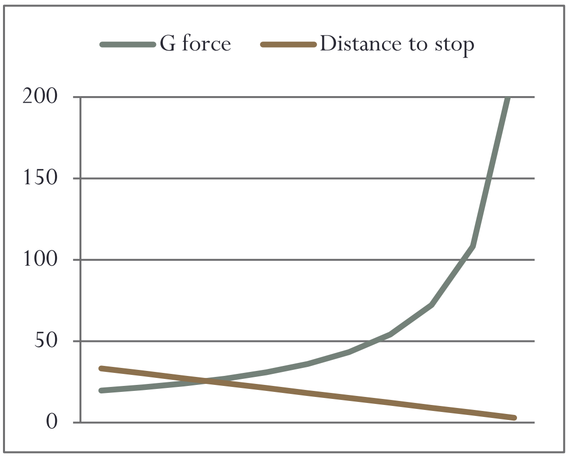
PHYSIQUE CONTEXT

To understand the factors involved in the deceleration, it's important to realise that a continuous deceleration is the ideal situation to provide the lowest G force in a given distance to stop a skater. A continuous deceleration is function of the initial speed (m/s) at the impact over the time it takes to stop, and that time is function of the distance to stop (m).

$$Continious\ deceleration = -\frac{speed^2}{2\ x\ distance}$$

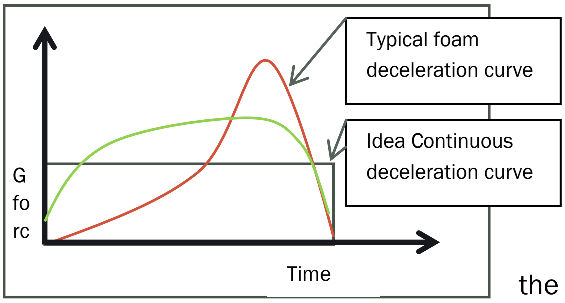
The deceleration divided by the gravitational acceleration of 9.81 (m/s²) give the G force value. Looking at a theory graph (1) of a system that could provide a continuous deceleration; it showing the variation of G force has the distance to stop decrease. It became evident that increase the distance to stop the skater is a good option to be able to decrease the G force. Unfortunately, this simple formulas work only in the case of a continuous deceleration witch is never the situation with foam padding.

GRAPH 1 G FORCE FUNCTION OF THE DISTANCE TO STOP DURING CONTINUOUS DECELERATION



The foam usually resists against the impact with less force at the beginning and more toward the end. Within his molecular structure, the foam has some room to be compress at first.

GRAPH 2 DECELERATION CURVES



From the graph 2 we see that the typical foam (red) doesn't offer an ideal solution. To improve the system we need to increase the G force at the beginning and decrease the peak G force toward the end so that the curve will look like the green curve on the graph.

Usually mats on boarded rink, have two foams one with a lower density at the front and one with higher density foam at the back. The reasons is to comply with the skaters shape has he make contact. Also, to use the softer foam for small impact and harder foam for higher impact since the skater will go deeper into the mats at high speed. If we reverse the mats, the foam at the front will be too hard for low impact. This all make sense and it also suggests that the option is to modify the second section of the curve toward the end.

From simple observation of international evens, it looks like only board less rink system show a real improvement to reduce G force impact. We can see the skaters having more distance and time to stop by pushing the mats and going deep into the system.

FIGURE 2 IMPACT IN BOARD LESS SYSTEM

FIGURE 3IMPACT IN BOARD RINK SYSTEM

The capacity of the mats to resist varies with the energy the skater at the impact. That energy is function of his mass and speed. The formula of kinetic energy (KE) is:

$$\mathrm{KE} = \frac{1}{2}\mathrm{m}v^2$$

From that formula, we can see that for a given skater, his energy is highly affected by his speed. For the mats to be efficient it becomes evident that the problem is the speed of the skater. Since the mats has limited capacity to decelerate the skater going at deferent speed, it become evident that a good solution is to reduce the speed at the beginning of the impact has much as possible so that the skater never squeeze the mat to his limit to keep the G force low.

To be able to reduce the speed without acting too much on the mats at the end will be the idea.

The solution is to move the mats forward and to place a soft mat between the current mats and the board. Further test and explication will follow in the document.

GENERAL METHODOLOGY

All the testing has been done by using an object to be drop vertically at different height into mats lying down on the cement floor.

All the measurement of the height had been done by measuring, with a tape measure, the distance under the object to the top of the mats surface to get the distance between the object and the mats.

An accelerometer attach to the object was measuring the G force value of the impact.

FIGURE 4 SNAPSHOCK ACCELEROMETER

The accelerometer is the SnapShockPlus model SSP-4000-3d 300G from IST (Instrumented Sensor Technology, Inc. 4704 Moore St.Okemos, MI tel: 517-349-8487

Highlights:

- Self Contained Acceleration Event, Date, Time Recorder
- Triaxial Accelerometer Models 300G
- Measures & Records Peak Shock Level, Duration, Velocity Change, Date & Time
- G-Trigger Levels 5.866G or Velocity-Change Trigger Levels 4.320
- Stores up to 5900 Readings
- Rugged, Water-Resistant Housing
- Mode Cycle Push-Button for Easy Manual Activation/De-activation
- Battery-Powered 9 volt, 8 to 30 + Day Operation
- Very Small Size: 1.5"x3.2"x1.5", 7oz.
- Built-In Piezoresistive Accelerometer
- Excellent Low Frequency Response
- Automatic Offset Correction
- Programmable Low Pass Filters
- 12 Bit A/D for Improved Accuracy
- 1200 Hz Digitization Rate
- Download via IRDA USB.
- Windows 95/98/NT/Me/2000/XP Setup & Analysis Software

The object of 33.5kg use for the ISU protocol has a circular contact surface of 20cm of diameter with and accelerometer attach to it. Note that the ISU protocol use 32kg so because the mass is 33.5 instead, all the data are showing higher G force then it will be at 32kg.

The accelerometer is bolted to it.

FIGURE 5 IMPACT OBJECT OF 33.5KG

An electric 12 volt car trunk release was use to drop the object and a manual winch to lift the object to the specific height.

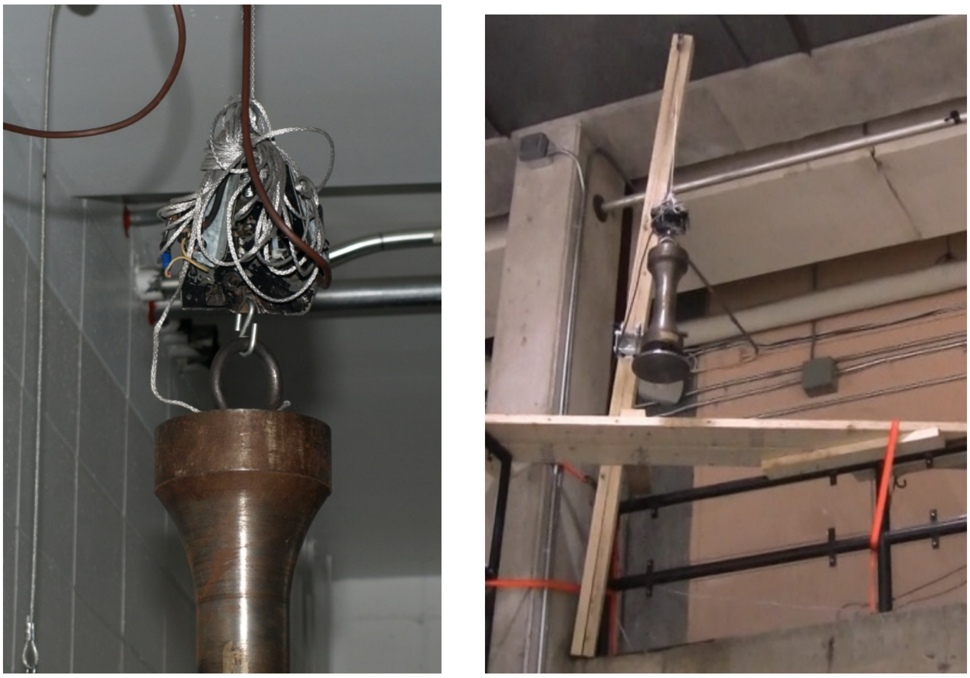


FIGURE 6 RELEASE SYSTEM

The mats where lay down on the cement surface surrounding by other mats to protect from any rebound when the object impact the mats.

For each drop, the mats on the floor were moved to prevent the next impact to be at the same spot.

FIGURE 7MATS ON THE FLOOR

The mats used were:

- Montréal Maurice Richard 20cm mats. (bi-foam)

FIGURE 8 20CM MTL MAT

- AD-Mat 20cm (10cm in front of Celcor 1095 and 10cm of Celcor 1555 in the back)

FIGURE 11 20CM AD-MATS

- Ste-Foy 20cm padding (The stiffest from all of them mono foam)

FIGURE 12 20CM STE-FOY

- Montréal Maurice Richard 30cm padding (bi-foam)

FIGURE 9 30CM MTL

- Ste-Foy 30 cm padding. (Stiffer than the 30cm of MTL mono foam)

FIGURE 10 30CM STE-FOY

For the additional short mats use:

Short mat Quebec:

(60cm height, 35cm deep, 225cm long) was place under the mats. It's has holes of 15cm by 15cm at every 15cm. The side foam has 10cm thick. The foam is an open cell polyurethane with a density of 16kg/m³ and a value of IFD (Indentation Force) of 115N.

- The cover is ventilated all around and the vinly use on the side has 18 oz/pi2 (1000 x 1300 Denier)

Figure 13 Short mat QC

Figure 14 Short mat QC

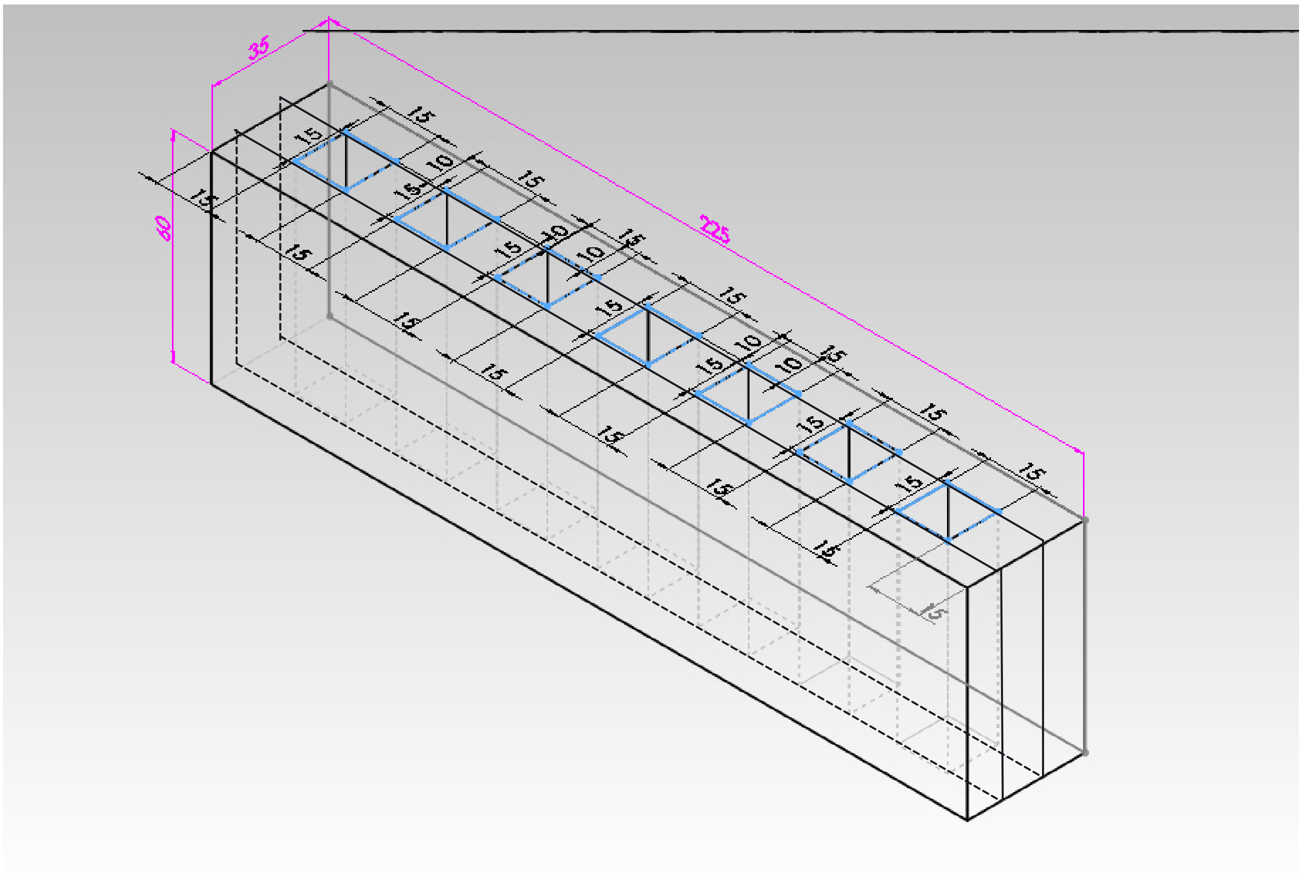


Figure 15 Short Mat QC dimension

Short mat Oval:

That mat is the mats use at the oval in Ste-Foy for long track. It's very old; they have been made in 1987. They also have holes and close cell foam at the back.

FIGURE 17 SHORT MAT OVAL

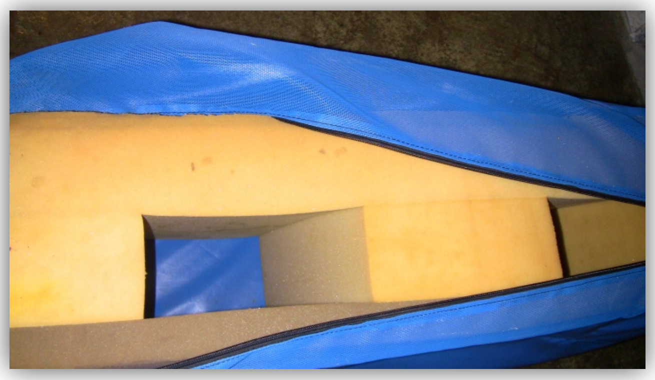


FIGURE 16 SHORT MAT OVAL

Short mats Chicoutimi

Those mats are triangular with ventilation and no holes.

Short mats Sherbrook

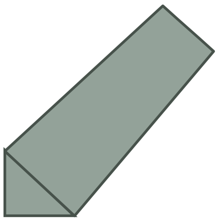


FIGURE 18 SHORT MATS TRIANGULAR

Those mats are triangular with ventilation and no holes.

They are softer than the triangular from Chicoutimi.

Question 1: What is the variability of the results from testing with the ISU protocol?

Methodology:

Look at the average of standard deviation of multiple drop tests from different drop height and different mats.

Results:

The average standard deviation of all those tests is 0.25.

Mats	Drop	G force	Average	Standard deviation
2x20cm MTL	2m	16.941	15.909	0.64484192
2x20cm MTL	2m	15.529		
2x20cm MTL	2m	15.902		
2x20cm MTL	2m	15.236		
2x20cm MTL	2m	15.936		
2x20cm MTL	3m	21.280	20.870	0.27874405
2x20cm MTL	3m	20.811		
2x20cm MTL	3m	20.683		
2x20cm MTL	3m	20.706		
2x20cm MTL	3.55m	23.387	23.435	0.08162961
2x20cm MTL	3.55m	23.529		
2x20cm MTL	3.55m	23.388		
30cm+20cm MTL	1m	9.882	9.989	0.11028439
30cm+20cm MTL	1m	10.102		
30cm+20cm MTL	1m	9.982		
30cm+20cm MTL	2m	15.354	14.734	0.57114618
30cm+20cm MTL	2m	14.619		
30cm+20cm MTL	2m	14.230		
30cm+20cm MTL	3m	17.867	18.100	0.25111254
30cm+20cm MTL	3m	18.067		
30cm+20cm MTL	3m	18.366		
30cm+20cm MTL	3.4m	20.072	19.986	0.19584993
30cm+20cm MTL	3.4m	19.761		
30cm+20cm MTL	3.4m	20.123		
2x30cm MTL	1m	8.941	9.019	0.13567731
2x30cm MTL	1m	9.176		
2x30cm MTL	1m	8.941		
2x30cm MTL	2m	13.176	13.019	0.27135463
2x30cm MTL	2m	13.176		
2x30cm MTL	2m	12.706		
2x30cm MTL	3m	16.471	16.314	0.27193198
2x30cm MTL	3m	16.471		
2x30cm MTL	3m	16.000		
2x30cm MTL	3.3m	17.597	17.556	0.03521993
2x30cm MTL	3.3m	17.536		
2x30cm MTL	3.3m	17.536		
75cm MTL	1m	8.471	8.471	0
75cm MTL	1m	8.471		
75cm MTL	2m	13.420	12.945	0.6708518
75cm MTL	2m	12.471		
75cm MTL	3.2m	18.033	17.832	0.20054398
75cm MTL	3.2m	17.830		
75cm MTL	3.2m	17.632		
2x20cm MTL + Short mats Oval	3.2m	12.878	12.805	0.10337727
2x20cm MTL + Short mats Oval	3.2m	12.732		
				Average
				0.2548377

Discussion:

From the results, the standard deviation is very low. For the purpose of this testing result, small variations within 1G are not so important; we are looking at significant differences. The fact that the standard deviations are small makes each drop test relatively easy to repeat with comparable results. The height and the positioning of the mats are the two major factors that could influence the data. Other factor like the variation of the density of the foam within the same mat or within a numbers of mats is possible; the years of the foam, the humidity within the foam, the ventilation of the mats, the cover of the mats and many others factors could also influence the results.

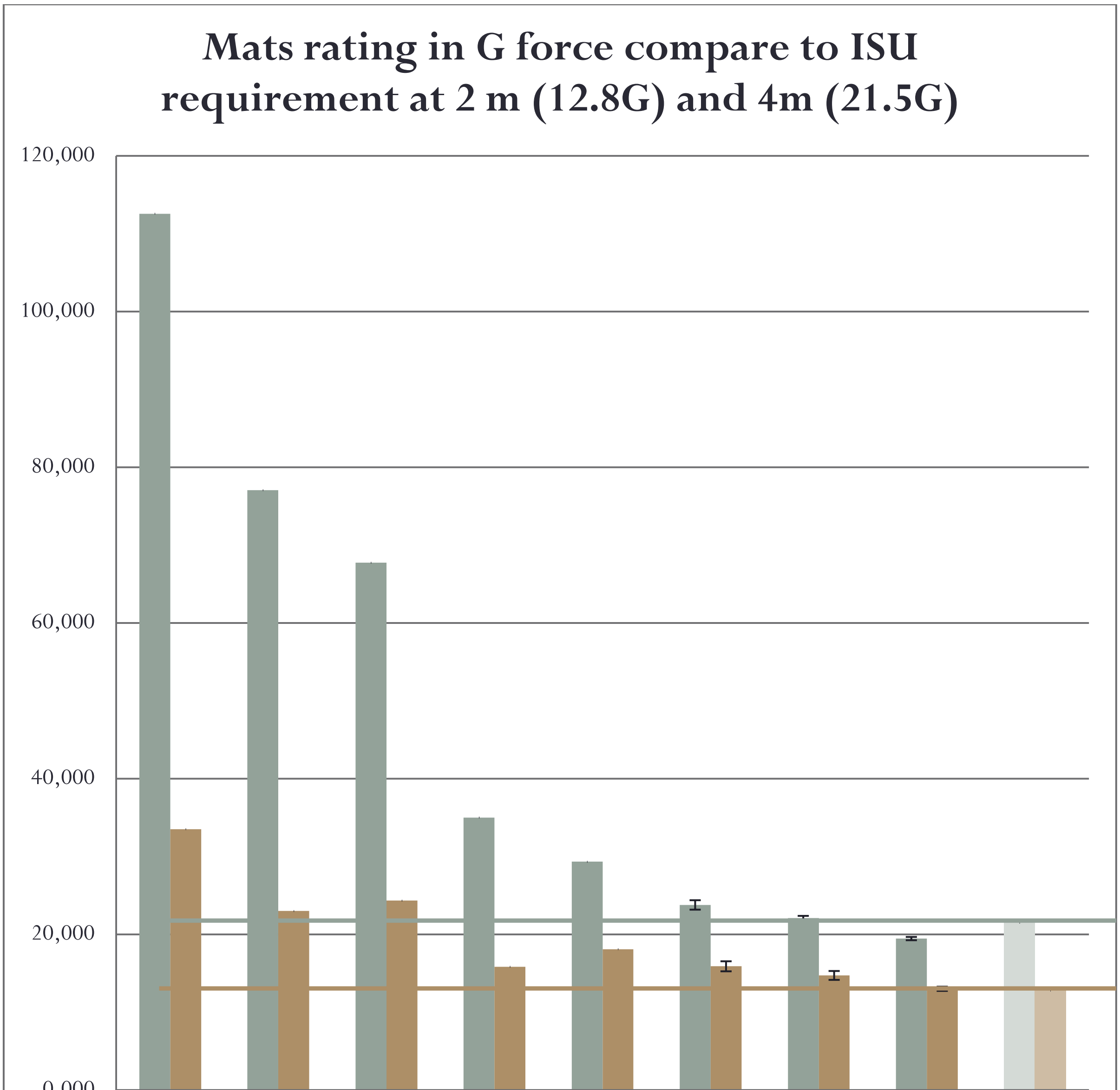
In this document, most of the tests results have been done with one single drop test, when multiple drops have been use, the average of the drops have been used and the standard deviation is visible on the graphs.

QUESTION 2: HOW SOME MATS OF 20CM AND 30CM ARE PERFORMING?

Methodology:

ISU drop tests at 2m and 4m on different mats that represent most of the clubs situation compare to the ISU requirement. G force.

Results:



	20cm MTL	20cmAD-Mats	20cm Ste-Foy	30cm MTL	30cm Ste-Foy	2x20cm MTL	30cm +20cm MTL	2x30cm MTL	ISU
4m	112,587	77,066	67,754	35,019	29,336	23,790	22,112	19,468	21,5
2m	33,521	23,005	24,345	15,846	18,105	15,909	14,734	13,019	12,800

Discussion:

Most of the test results have been done with a single drop test, when multiple drops have been use; the average of those drop test is used and the standard deviation is visible on the graphs. It is the case for the 2x20cm, 30cm+20cm and 2x30cm for those results.

Those different mats represent most of the current situation in clubs in Canada. Some clubs has stiffer mats than other and some has thicker mats than others.

The stiffness from those mats is rank in this order:

- 20cm MTL soft
- 20cm Ad-Mat medium
- 20 cm Ste-Foy firm
- 30cm MTL medium soft
- 30cm Ste-Foy medium

From the results, at 4m drop, the 20cm MTL is too soft; the object had bottoming out to reach 112G. The 20cm Ste-Foy is firm and it was able to absorb more energy showing a lower G force at 4m from all those 20cm mats. When the mats are firm, it’s harder to squeeze the mats and it’s harder to bottoming out. But, because the mat has only 20cm, even if the mats is firm, the G force values are still too high to protect the skaters. Those mats do not provide enough time to stop the object. The deceleration happens to quickly.

At low impact speed, 2m drop, the 20cm MTL did not perform very well, still too soft, the object squeeze the mat too easily leaving again not enough time to stop the object. The firm Ste-Foy 20cm is not do well ether compare to the ISU requirement. At the end, the results for the 20cm mats show that it’s just not enough mats to protect the skater.

The 30cm mats are better than the 20cm mats. Like the 2x20cm, 2x30cm and the 1x20cm+30cm, it could be ok for slower skaters if the mat is not too firm. Those mats are closer to pass the ISU requirement at 2m. But in the case where the mats would be stiffer, it would not protect well for low impact because the skater would not be able to go deep enough into the mats during the impact resulting with a relatively high G force again. At 4m drop is like the 20cm, it’s just not enough mats to protect the skater according to the ISU requirement. It also matches the injury statistic in the last few years.

The only combination of mats that pass the ISU requirement is the 2x30cm. Not many if any clubs in Canada put 2x30cm for competitions or trainings.

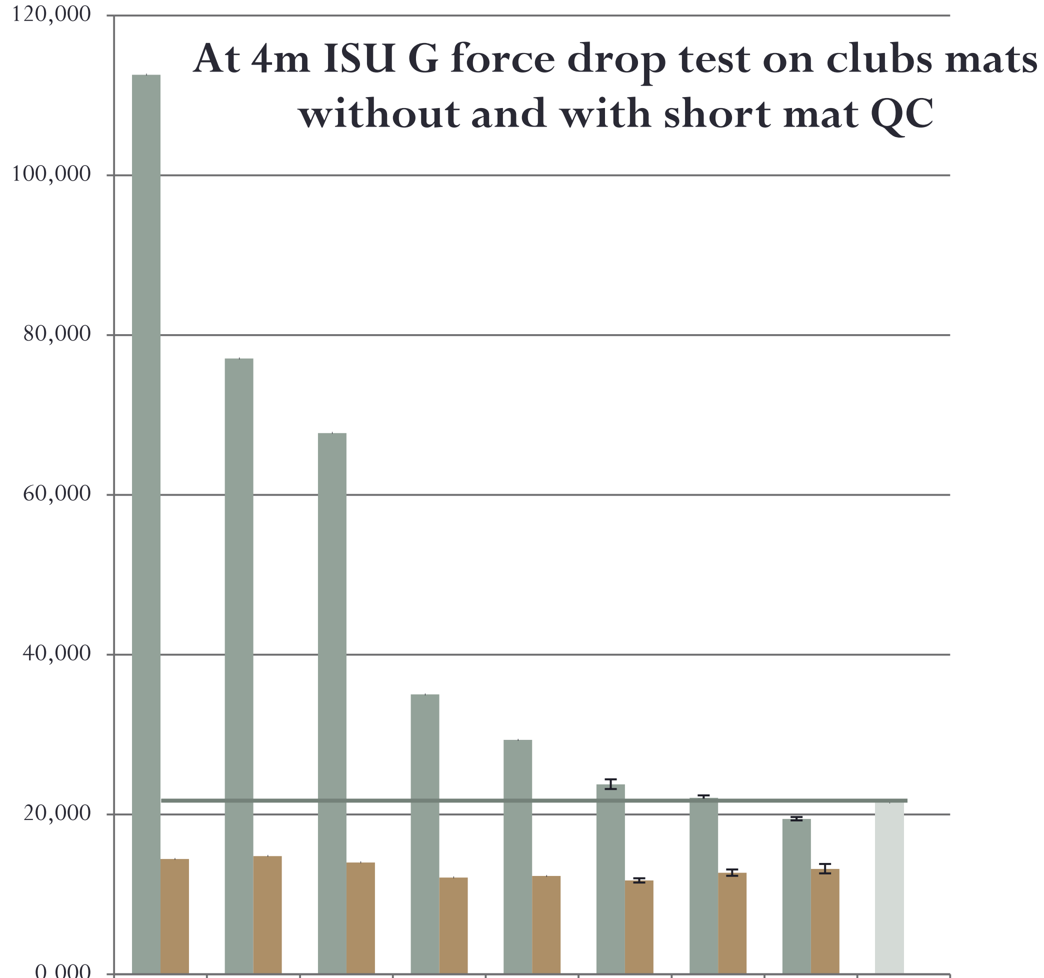
Looking at the results it’s clearly show better performance as the total thickness increase. That is no surprises since more padding usually give more time and distance to stop.

Question 3: What is the score by adding more mats at 4m?

Methodology:

Drop test on the clubs mats without and with an additional short soft 35cm mats with holes (Short mat QC) behind the each of them.

Results:



	20cm MTL	20cmA D-Mats	20cm Ste-Foy	30cm MTL	30cm Ste-Foy	2x20cm MTL	30cm +20cm MTL	2x30cm MTL	ISU require ment
Alone	112,587	77,066	67,754	35,019	29,336	23,790	22,112	19,468	21,5
with short mat QC	14,437	14,815	14,017	12,130	12,307	11,748	12,720	13,217	

Discussion:

Most of the test results have been done with a single drop test, when multiple drops have been use; the average of those drop test is used and the standard deviation is visible on the graphs. It is the case for the 2x20cm, 30cm+20cm and 2x30cm for those results.

The results are very interesting, the additional mat clearly show excellent performance surpassing the ISU requirement by more than 28% across all different mats. It's an interesting result because it could by an easier solution for most of the clubs to add those short mats instead of having to replace all the mats.

It's also important to keep in mind that this solution show great result on the ISU test. The ISU test doesn't represent the value of a real skater.

The best performance was with the 2x20cm with the short mats QC, interesting to see that more mats from that point didn't do better. Probably because the additional mats are very soft compare to the front mats so that the ratio of thickness from soft mat compare to stiffer front mats decrease.

- 2x20cm + 35cm = 35/40 =0.875
- 3x30cm + 35cm = 35/60 =0.583

A test at 4.73m with 2 x 20cm MTL+30cm MTL= 20.7G compare to 2x20cm MTL+35cm (short soft mats Oval) = 16.3G. The object bend the 3x20cm MTL and goes deeper into the short soft mat Oval compare to the stiffer 30cm MTL. This is showing that the mats behind cannot be to firm. But with a lot heavier impact object or a much higher drop test, the result should be different since in general the more energy the object has at the impact, more firm mats has to be. If the mat is too soft, the object is bottoming out the mats.

With the additional short mats QC, the 1x30cm performs as good as the 2x20cm so that's interesting because it's the situation of many clubs.

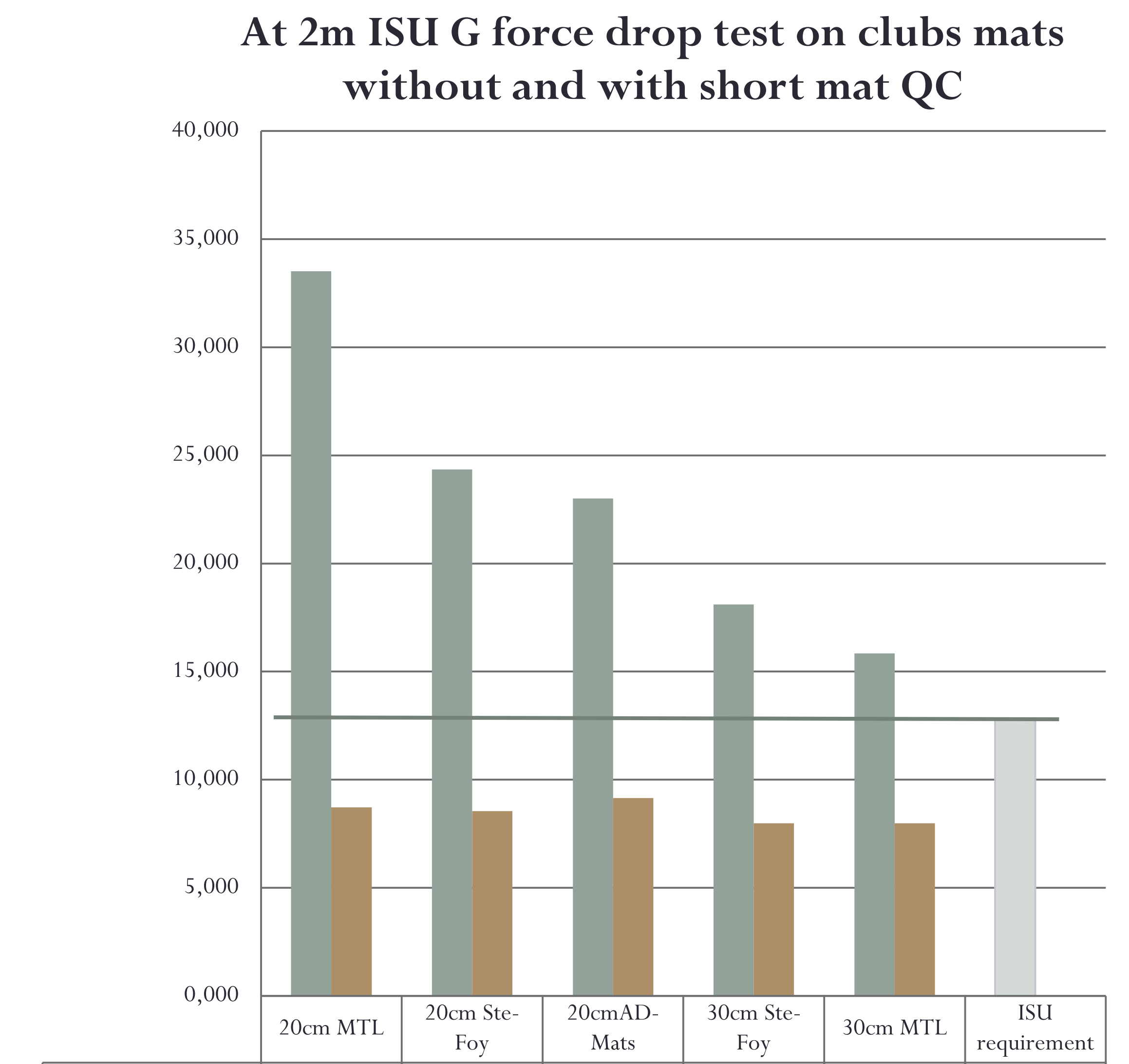
With the additional short mats QC, the 1x20cm did well too but again, the 2x20cm or the 30cm has more potential for an impact at higher speed. Also since at the impact the mats bend a lot, the front mats have to be well attach to each other. Also, the stability of the single 20cm mats is to be consider, it could be not feasible to using only 20cm in front of the short mat, if the mats can't stand up by itself.

QUESTION 4: WHAT IS THE SCORE BY ADDING MORE MATS AT 2M?

Methodology:

Drop test on the clubs mats without and with an additional short soft 35cm mats with holes (Short mat QC) behind the each of them.

Results:



	20cm MTL	20cm Ste-Foy	20cmAD-Mats	30cm Ste-Foy	30cm MTL	ISU requirement
2m	33,521	24,345	23,005	18,1	15,846	12,800
with short mat QC	8,714	8,548	9,155	7,981	7,981	

Discussion

The test results have been done with a single drop test.

The result show at 2m also great performance and surpass the ISU requirement by 28% too. The short mats QC provide excellent protection at low and high impact witch also represent a typical situation in clubs who has some fast and slower skaters in the same training or with the same setup for padding.

Question 5: What is the behaviour of those short mats?

Methodology

The video was used to collect observation to understand some variation in profiles

Observation:

Figure 19 Short Mats QC

The additional mat is softer than the frontal mats, just by walking on it, the foot goes deep down. The front mats bend during the impact so that part of the energy is transfer laterally.

Front the top view, the black arrow represents the skater force going into the mats. To balance the force acting into the mats, the length of that force has to be the same than the sum of the force acting by the mats represented in white. That draw show that part of the force is dissipating laterally. We can see on the picture the impact object going deep into the mats and pulling of the side mats.

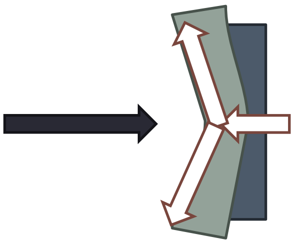


Figure 20 Forces acting during impact

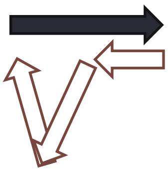


Figure 21 Sommation of forces

Figure 22 Top mats side by side

Another advantage to place it behind is to use the stiffer front mats to increase the surface contact to act on the soft mats behind. Since skater has different position that will affect the pressure has the surface contact vary. The result show with the soft MTL 20cm mats is bottoming out when the surface of contact is small. By having the stiffer mat in front, has it bend, it increase the surface contact behind reducing the pressure.

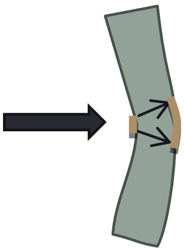


Figure 23 Surface contact at impact

The short height of the additional mats prevents the skater to slide under. The front mats stay on the ice during the impact when the skater hit them by the ice which is most of the cases. As the skater hit the mats nothing restricts the top of the mat to bend because there is no foam behind to support the top half. With a full size mat behind the top will not bend has the skater hit the bottom of the mats and it will open a space under the mats.

This illustrates the ide, a short size mat behind compare to a full size mat behind.

Top, front and side view short mat

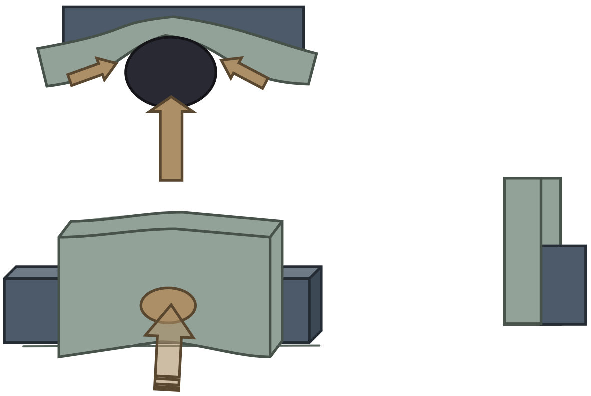


FIGURE 25 DEFORMATIONS WITH SHORT MAT BEHIND

Top, front and side view full size mats behind

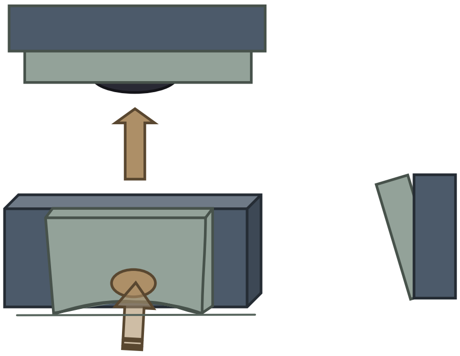


FIGURE 26 DEFORMATION WITH FULL SIZE MAT BEHIND

FIGURE 24 IMPACT WITH SHORT MATS BEHIND

FIGURE 27 IMPACT WITH SHORT AND FULL MATS BEHIND

With a full size mats behind, from the picture on the right, we see the mats in angle (creating a space under) compare from the picture on the left with only a short mat behind.

We can also see skater going under the mats on board less system. The top strap is too tight and doesn't alloy the top of the mats to move with the bottom of the mats.

FIGURE 28 SKATER GOING UNDER, MATS LEAN AT THE BOTTOM

The disadvantage of having a short mat behind is the angular rotation that's creates when a skater hit the mats at the top. Even if it's rarely happening compare to a lower impact it does happen sometimes. It's a compromise, short mats behind improves the low impact by the ice by limiting the opportunity for a skater to glide under but it may create some problem when the skater hit the top of the mats.

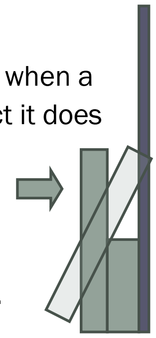


FIGURE 29 IMPACT AT THE TOP

On the picture the short mats is on the left and the object was drop on the right side. We easily see the rotation of the mats.

FIGURE 30 IMPACT AT THE TOP

From a test at 2m drop, even if no padding is behind at the top, the mats has to bend before to hit the board and that still reduce the G force at 2m from 33.52 to 10.31.

TABLE 1 DROP TEST AT THE TOP AT 2M IN G FORCE

20cm MTL	2m	33.52G
20 cm MTL + shot mats and impact at the top	2m	10.31G
20 cm MTL + shot mats	2m	8.714G

It's possible that the rotation of the mats cause injuries if the skaters hit at the top of the mats. Those situations will need a close look and monitoring in real skating situation.

A drop test at 4m with the 20cm Ad-Mats and the short mat QC under the mats with the impact by the ice (picture on the left) scored 15.76G and with the impact in the middle of the mats (picture on the right) score 16.31G .

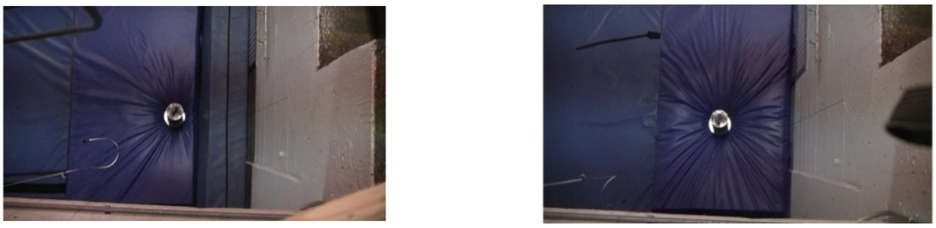


FIGURE 31 IMPACT CLOSE TO THE ICE AND IN THE MIDDLE OF THE MATS

This result show that for most of the cases when the skater is down on the ice or on his knees, it will work well. Again only when the skater jump at the very top of the mats, that injuries are more likely to happen because of the rotation of the mats.

On the pictures we can see the mats rotate when the skater hit the top of the mats.

We also see the need to have those mats well attach to each other. When the mats move back they pull the side mats and could separate if they are not well attach to each other.

But at the end, in this case no injury.

FIGURE 32 SKATER HIT THE TOP OF THE MATS

In the future if this rotation at the top is a problem it will be possible to fix it with the addition on another small firm mat of 10cm than would reduce the angle. Because the front mats never compress total there is always a space at the top that could be fill to reduce the lean angle with a firm mats.

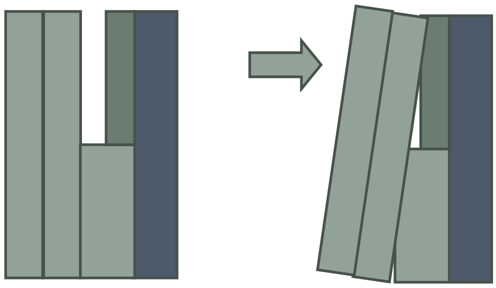


FIGURE 33 CONFIGURATION WITH UPPER MATS

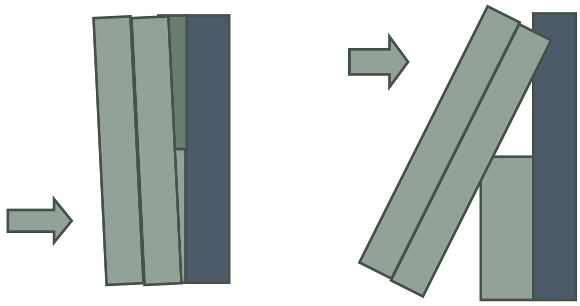
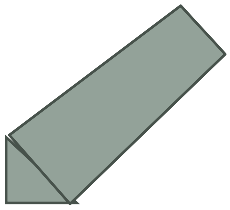


FIGURE 34 ROTATION OF THE TOP WITHOUT UPPER MATS

Again this situation may occur and it has to be look in real situation. But in 7 competitions in the Quebec province in 2011-12 with a setup with short mats behind, this situation had occur 3 times only and no injuries.

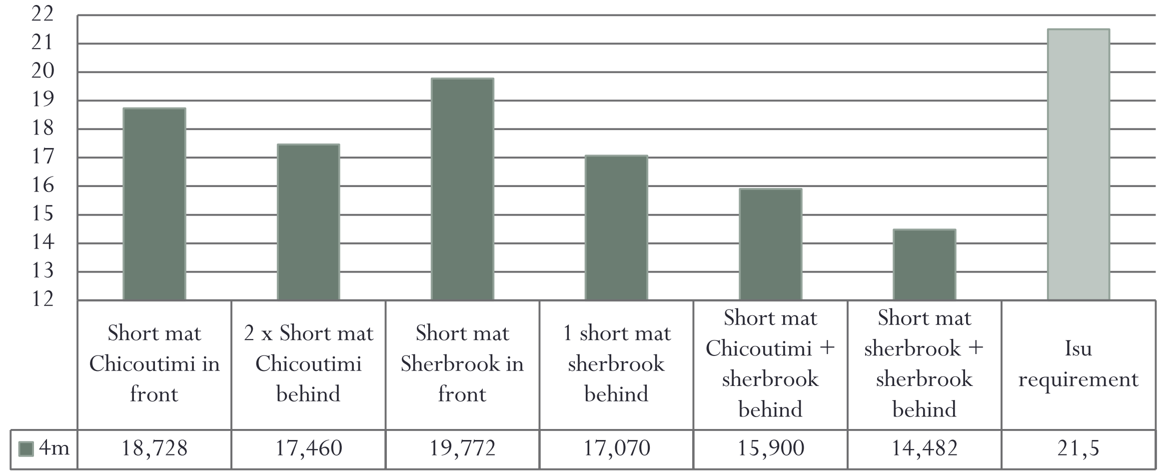
Triangular short mat from Sherbrook and Chicoutimi overview

Methodology



From testing different configuration with the triangular in front or behind or in front of the 20cm MTL the result at 4m are:

Results:



	Short mat Chicoutimi in front	2 x Short mat Chicoutimi behind	Short mat Sherbrook in front	1 short mat sherbrook behind	Short mat Chicoutimi + sherbrook behind	Short mat sherbrook + sherbrook behind	Isu requirement
4m	18,728	17,460	19,772	17,070	15,900	14,482	21,5

Discussion:

This test was done on triangular shape short mats use by Sherbrook and Chicoutimi clubs during their training. They use those triangular in front of the padding but they could also use those behind too.

The draw on the left show how they use those in training and how it was setup for the test in front of the mats. On the right, the setup used for the test behind the mats with one and two triangular mats.

Figure 35 Triangular short mats configurations

The results show that those triangular mats do reduce the G force compare to just the 20cm MTL that score 112G alone.

From testing those triangular short mats, they did better behind than in front.

With one single triangular shape, the efficiency is good (17G) when the impact occur on the ice level but as soon has it goes up to the middle part of the mats it's not good anymore since there is just not enough foam, the main mats just move to the board. The result in the middle of the padding was 27G at 4m when the ISU requirement is 21.5G so it doesn't pass. It's interesting to note that the mats used was the Ad-mats 20cm and that mats alone has 77.06G at 4m. So the fact that the mat has to bend does reduce the G force. So the triangular mats force the main mats to bend before to hit the board and that was good to reduce the G force from 77.06G to 27G. So using one triangular is still a lot better than none.

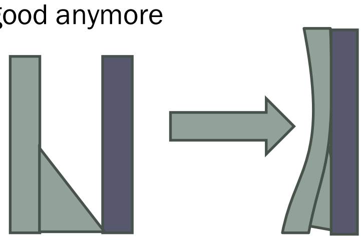


FIGURE 36, MOVEMENT OF THE MATS WITH A TRIANGULAR SHORT MAT BEHIND

With 2x 20cm in front, that has not been tested but it should just pass the requirement since with no short mats behind its score at 23.79G.

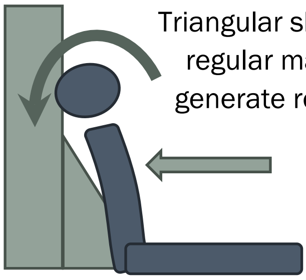


FIGURE 37, ROTATION WITH TRIANGULAR SHORT MATS

Triangular shape of short mats exist in some clubs they used those in front of the regular mat not behind. From testing, they do work well in front but they will generate rotation in many cases that could cause injuries.

For example, when the skater glides backwards sitting on the ice, his butts will stop first and can create a whiplash of the head into the mats. That situation happens on regular bases.

The triangular short mats are not ideal since they have to by attach to each other when they are combine to prevent the mats to split during the impact. The triangular need to be setup with the diagonal from the side view goes from the middle of the mat to the ice level by the board. If it's setup in the reverse way the impact will lift the mat. We can see on the picture the position after the impact when the setup is not correct.

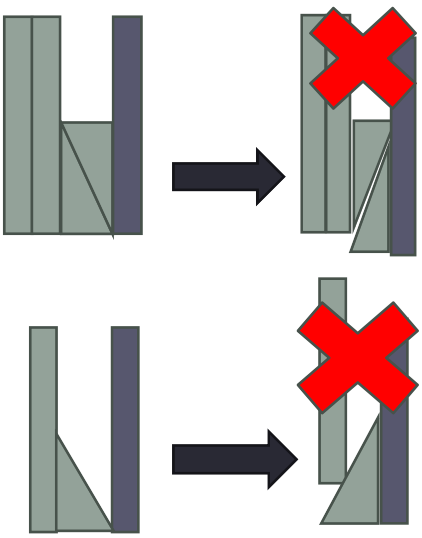


FIGURE 38, DIFFERENT POSITION OF THE TRIANGULAR SHORT MATS

FIGURE 39 TRIANGULAR SHORT MATS IN A WRONG CONFIGURATION

Also with one triangular, the front mats lean on the board easily when the skater doesn't hit close to the ice and it's creating a space under the front mats since they have a tendency to lift sometimes.

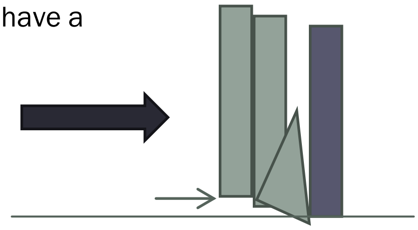
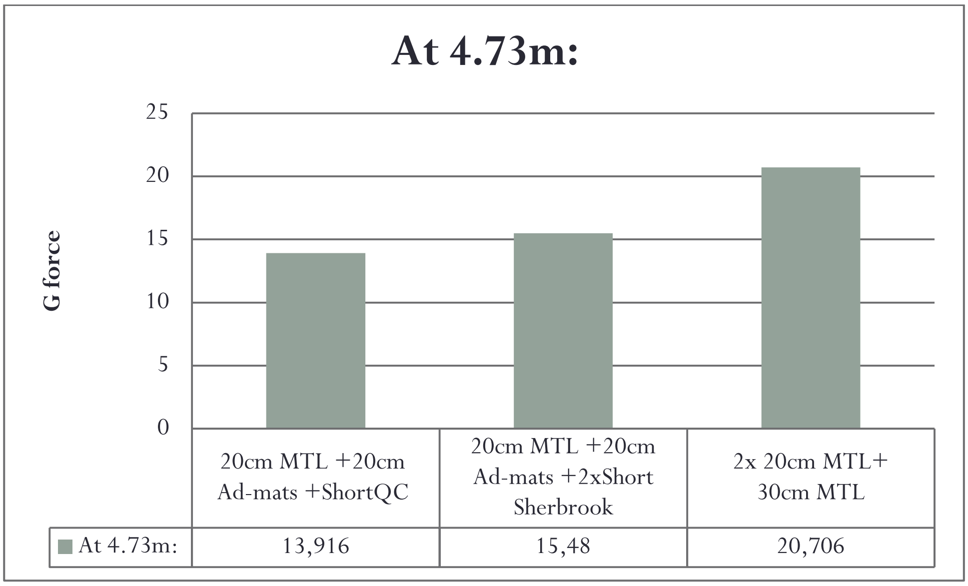


FIGURE 40, ROTATION OF THE TRIANGULAR SHORT MATS WHEN THE IMPACT IS IN THE MIDDLE

Another test perform at 4.73m, higher drop than the ISU protocol, show that those short mats both perform better than just adding a 30cm full size mats. The 30cm MTL is a lot more firm than the short mats and it's doesn't alloyed the front mat to bend.

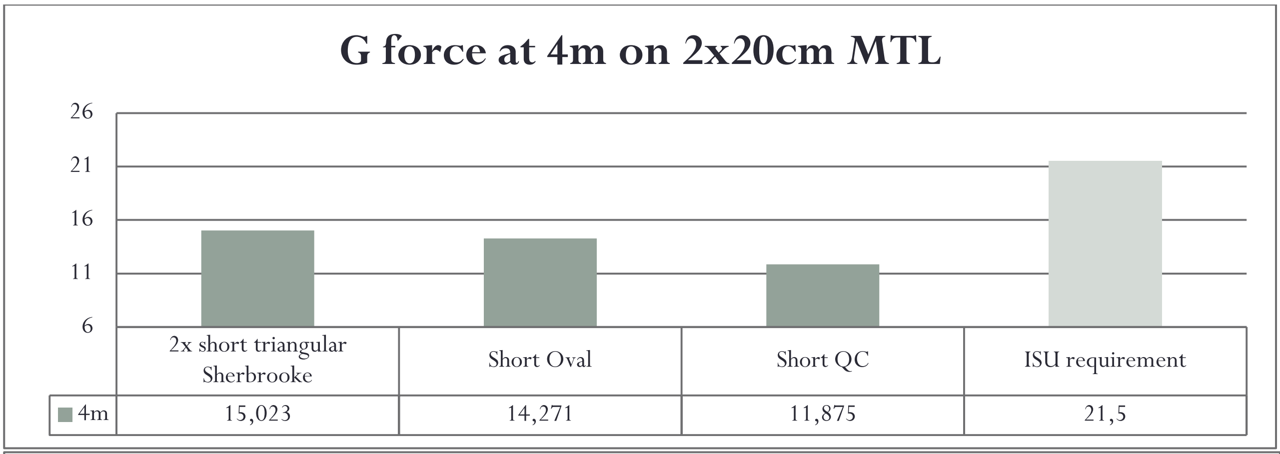


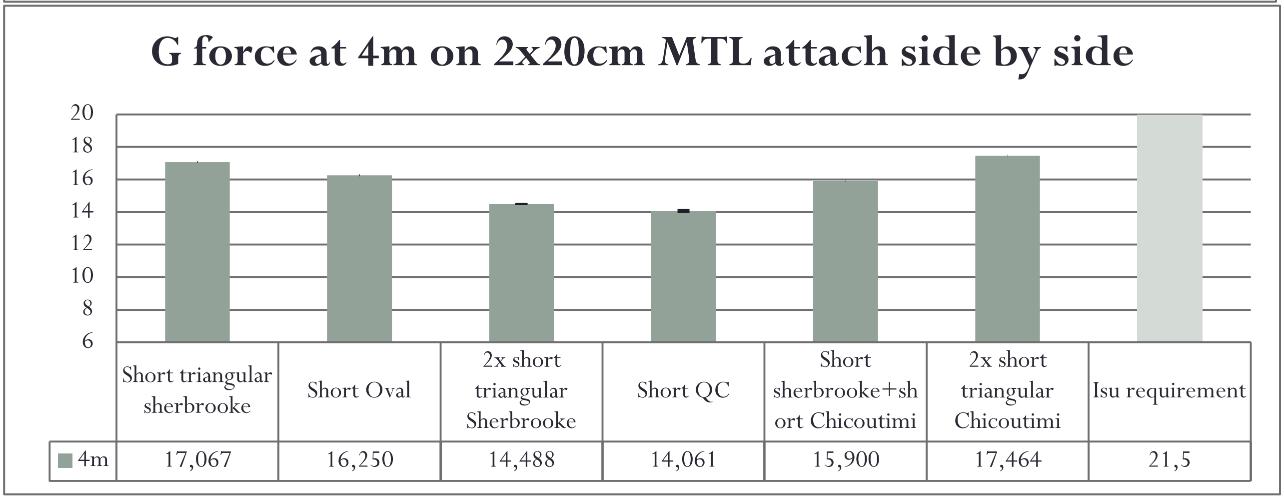
Question 6: How stiff the additional mats has to be?

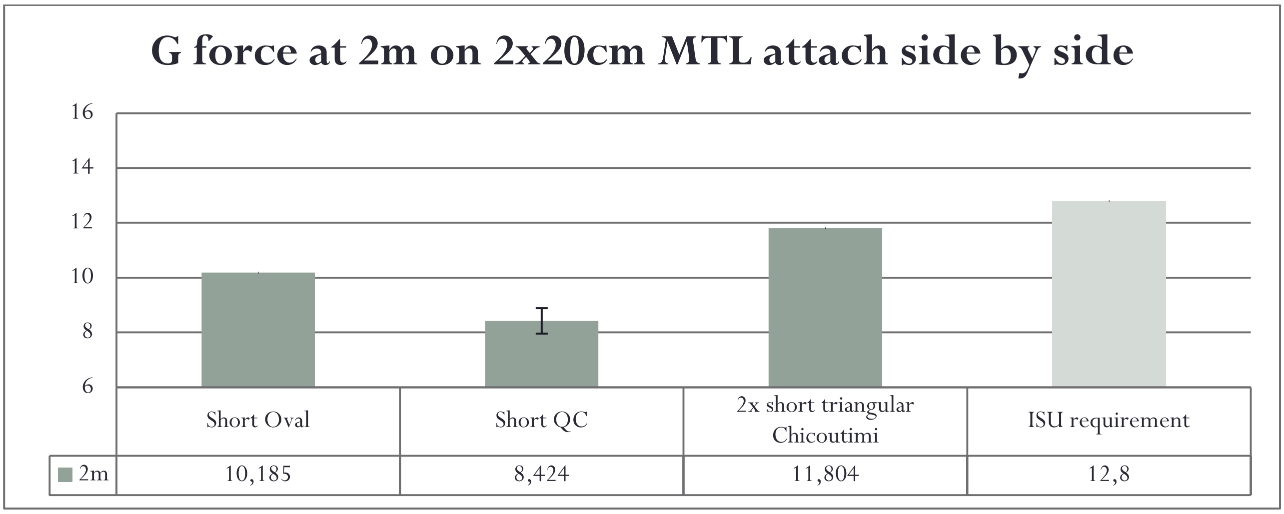
Methodology:

Test G force with existent shot mat behind 2x20cm MTL at 4m and 2x20cm attach side by side at 4m drop and 2m.

Results:







Discussion:

The ranking of those short mats in term of stiffness from soft to firm is:

- Very Soft - Sherbrook 1 triangular
- Soft - Oval
- Medium soft- Sherbrook 2 triangular
- Medium - QC
- Medium firm - Chicoutimi + Sherbrook
- Firm - Chicoutimi 2 triangular

The results show that short mats too soft will not offer enough resistance to the impact object and firm is too much resistance; the front mats doesn't bend as much and doesn't go deep enough into the short mats behind. Again those results could be different with a heavier and higher drop test.

The mats side by side is represented on the picture. Another important observation is the rebound is also more important went the short mats is stiffer.

On the right picture we see the object jumping up on the two triangular of Chicoutimi and on the left the object is not jumping on the 2 triangular of Sherbrook.

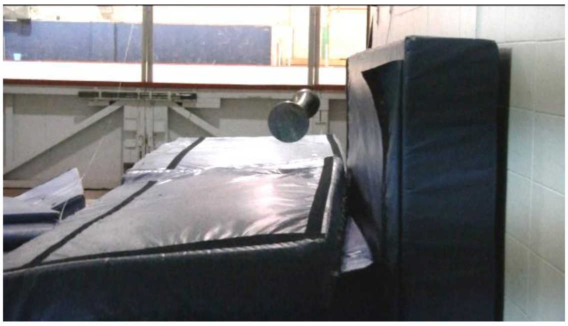


FIGURE 41, MORE REEBOND WITH STIFFER SHORT MATS ON THE RIGHT

This is an important observation, soft short mat provide less rebound but higher G force than stiff short mat that will show more rebound and probably a lower G force at very high impact.

WHAT ABOUT DIFFERENT CONFIGURATION:

Methodology:

Use different configuration with the short mats in between the mats to compare.

Results:

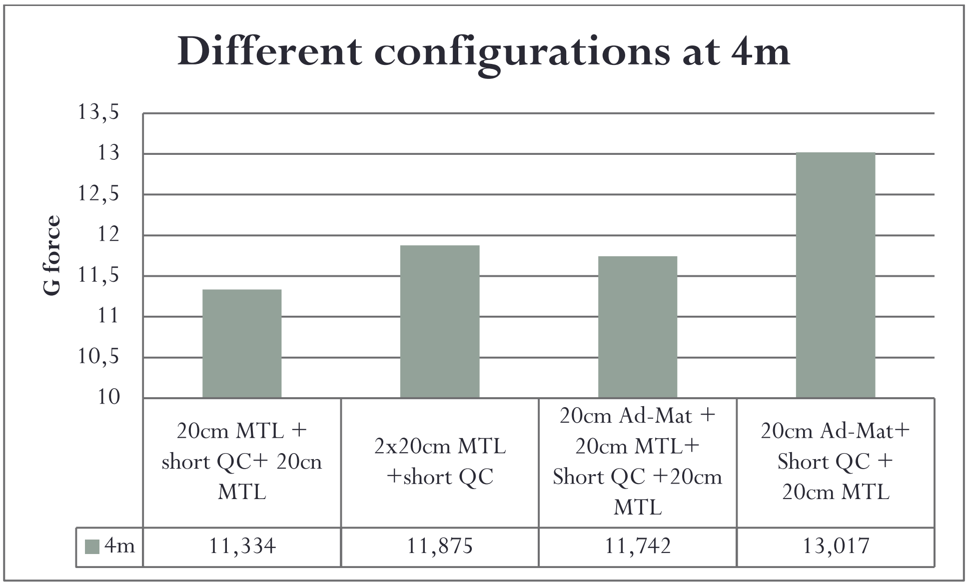


FIGURE 42, DIFFERENT CONFIGURATION

Discussion:

Those drops are all single drop test.

We see from the results that placing the short mats in-between is also efficient. This configuration has not been test in real life situation. It could be interesting for lower speed since it will need less energy to pull the side mats but at high speed more mats to move is probably better because it needs more energy, more total mass of mats to move.

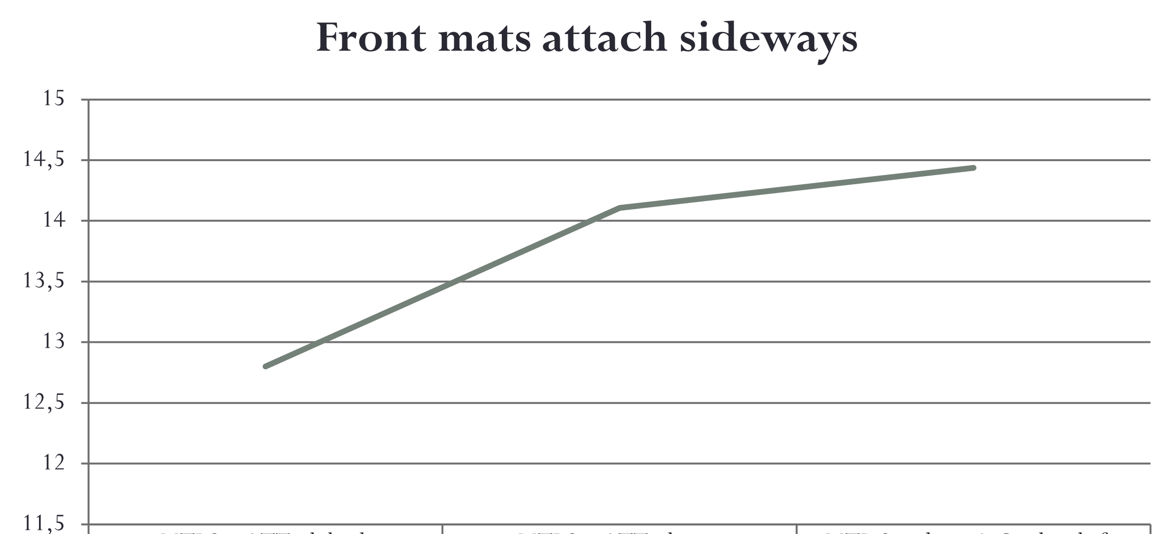
IS THE SIDE MATS INFLUENCE THE G FORCE

Methodology

The mats is attach sideways to one mats on one side and on two mats on each side.

FIGURE 43, DIFFERENT CONFIGURATION WITH ONE SIDE MATS ATTACH AND TWO SIDE MATS ATTACH

Results



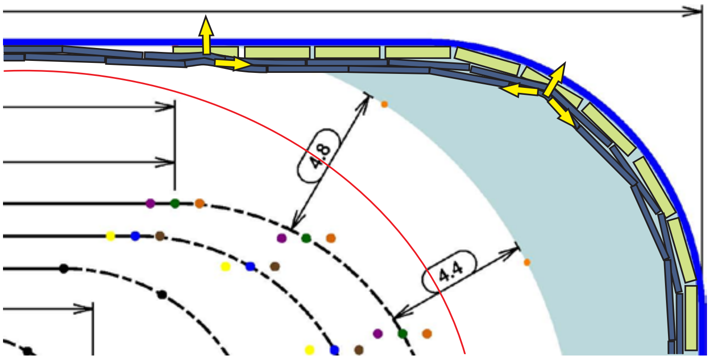
	MTL8in ATTach both side+Quebec haft-height	MTL8in ATTach one side+Quebec haft-height	MTL 8in alone + Quebec haft-height
4 m	12,801	14,108	14,437

Discussion

The side mats do influence the result, which shows the side effect of the mats pulling on each other during the impact.

It also important to note that will have more effect in the turn of the boards because on the position of each side mats.

It also important to note that, the effect, on the last short mat place before the straight, will be like having just one side mats. That is a critical spot, there will be more direct force on the mats and that will also give more rebound at the location we want to see less rebound.



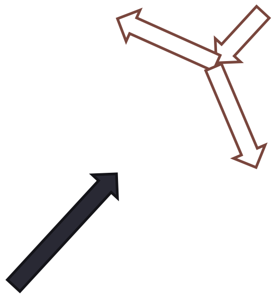


FIGURE 44, SIDE EFFECT ON THE TURN

Discussion on ISU protocol:

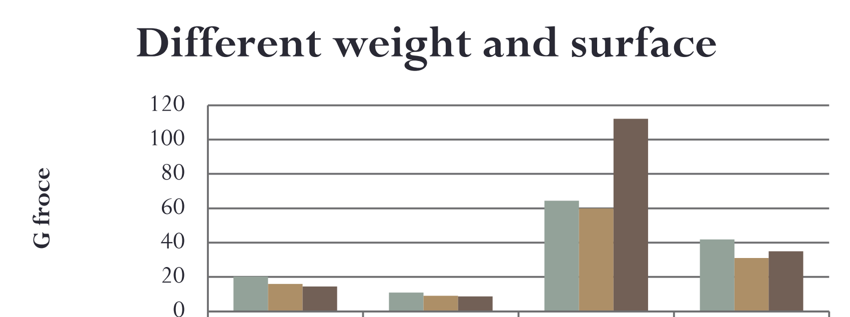
The ISU object has a small surface contact so the pressure is high compare to a skater who has a variable surface depending of his position at the impact. The pressure is the force divided by the surface so for the ISU protocol the pressure is for the object at 1G is:

P=F/s = (33kg x 9.81 m/s²) / 0.031416m² = 10461 pa (Pascal)

For an 80kg hypothetic skater with an approximate surface of 0.24m², the pressure is:

P=F/s = (80kg x 9.81 m/s²) / 0.24m² = 3270 pa (Pascal)

The skater has around 3 times less pressure than the ISU protocol in that case. To see what will be the result of the hypothetic skater with a surface contact of 0.24m² at 80kg and 40kg compare to the ISU protocol, a test had been done with bags of 20kg of calcium. The accelerometer was place between the bags.



	4m 20cm MTL + short mats QC	2m 20cm MTL + short mats QC	4m 20cm MTL	4m 30cm MTL
0.24 (80kg)	20,2	11	64,4	41,9
0.24 (40kg)	16	9	60	31
0.0314(33kg)	14,4	8,7	112	35

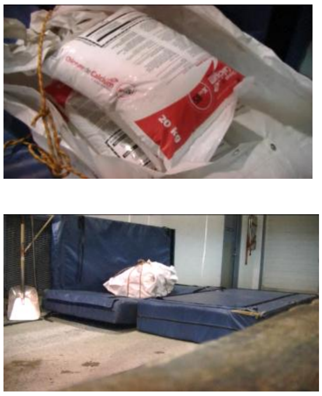


Figure 45, drop test with 20kg bags

From a test at 4m with 4 bags of 20kg (total 80kg) with a surface contact of 0.24m² dropped on the same 20cm MTL the result show 64.4G witch is lower than the 112 G but not 3 times less ether from the pressure difference between the ISU object and the hypothetic skater. In this case, the ISU protocol with the 20cm MTL had shown an overrate result compare to hypothetic skater protocols at 4m drop. The main reason been that with the ISU protocol the pressure is higher and the object had bottoming out.

In general when the object doesn't bottoming out, the ISU protocol will underrated the result compare to a real skater at 80kg because the ISU mass is 2.4 times lower than the skater at 80kg. But again it's not because it's 2.4 times lower mass that the G force result will be 2.4 times underrated. From the test on the 30cm MTL that score at 4m 35.019G with the ISU protocol, had score 41.945G with the 80kg bags also at 4m. This is not 2.4 times more it's only 1.2 times more mainly because the surface contact is bigger with the hypothetic skater.

From those two examples, because the deceleration is not consistent, is become almost impossible to have a formula that will correlate the ISU test from a real skater speed, body weight and shape. The only thing that the ISU protocol represents with precision is the ISU impact object going into the mats.

The ISU choice to have a small surface of contact for the object is partially to compensate for the lack of drop height and weight. A drop at 4m represent 32km/h and a lap speed around 13 sec. The drop test to be specific should go up to 9m to represent 48km/h and a lap under 9sec. By having a small surface of contact and a higher pressure, the ISU drop test allows the object to go deep into the mass to simulate a skater been heavier with a bigger surface and at a higher speed.

The ISU protocol is not a trough specific test that will give the reel value of G force from a skater impact but it's a simple protocol that allows comparing mats. Reel life observations and statistic on injuries is necessary to better know the performance of the mats. If we look at the ISU requirement, from all the different mats tested only the 2x30cm MTL pass the ISU requirement. This result drive to another question, is the ISU requirement good enough? With 2x30cm some injury occurs mainly at high speed at international evens.

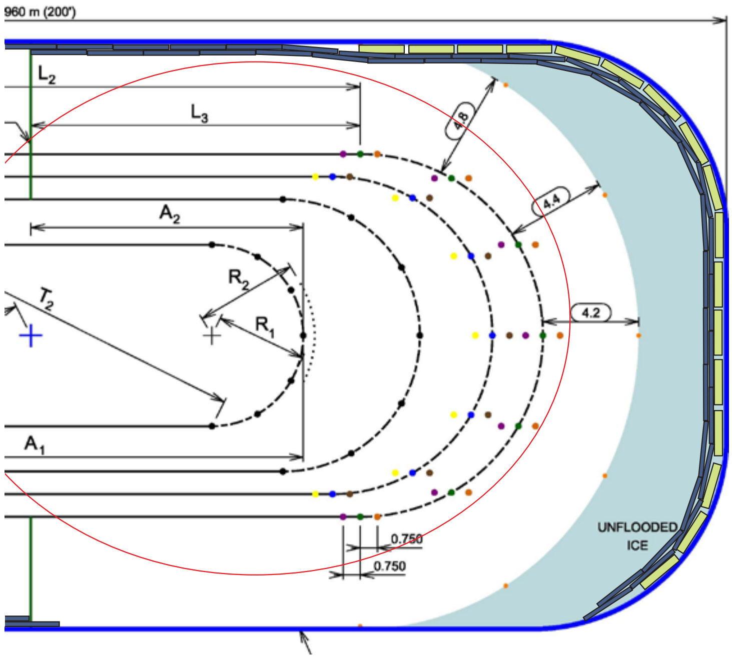
Recommendations:

The following are some recommendations base on 2011-12 season experience in training and competition with the addition of short mats behind.

Position of the short mats on the boards

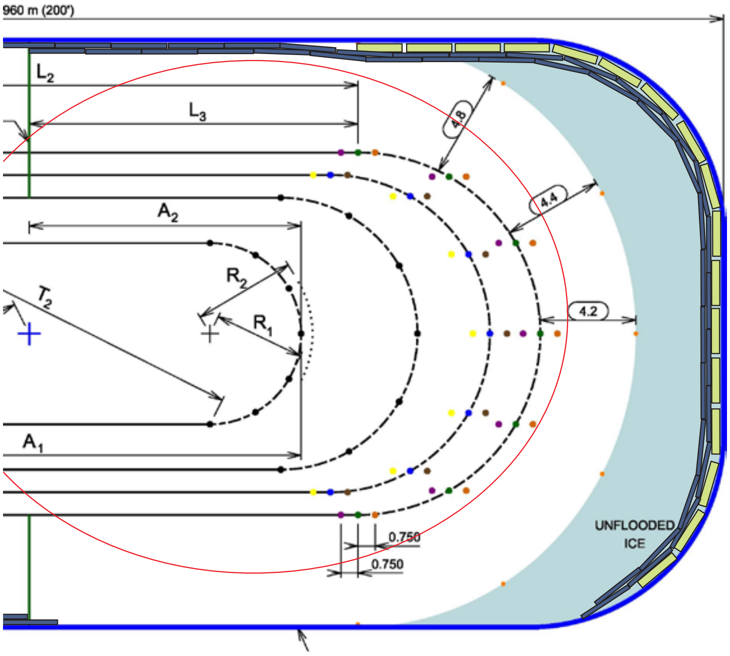
Those additional mats also reduce the space to skate on the ice at the exit of the turn. To avoid that problem, they can't be place in the straights; they have to be place only in the turn.

The first mats start in line with the middle track of the last marker. The skater doesn't feel the difference in space to exit the turn. On the draw the red line show a wide exit that doesn't interfere with the mats.

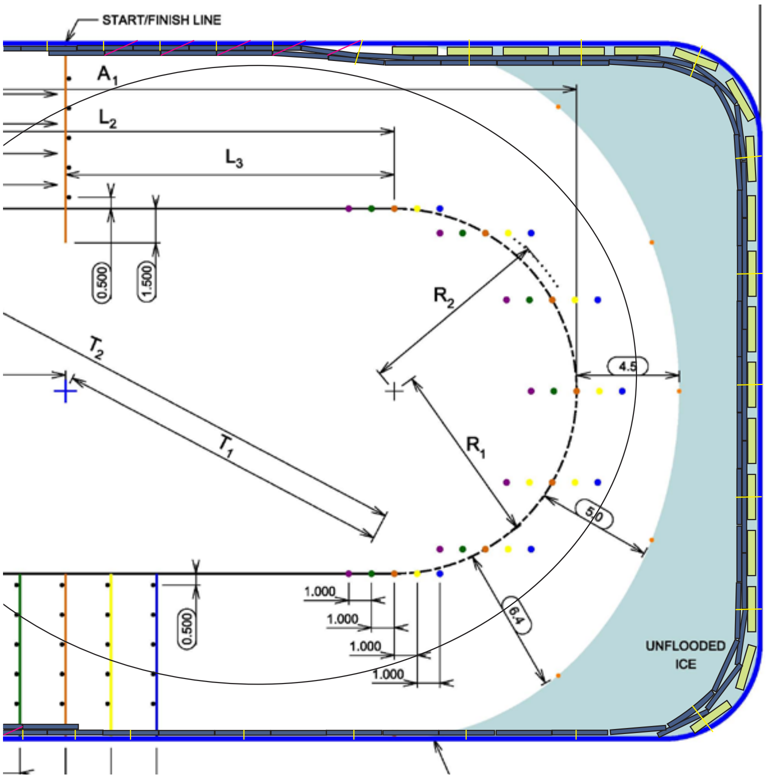


Numbers of additional mats

NHL size rink, 17x2= 34 total.



International size rink 18x2= 36 total



Training condition

This is a recommendation; experience will tell us more about it. They are place where the impact is not in an angle

2x10=20 total