東京理科大学「火災安全科学研究拠点」

■研究成果概要報告書

研　究　課　題		ベッドマットレスの ISO 試験法による火災リスク評価に関する研究	実 施 年 度 平成２４年度
研究代表者	所属	Fire Insurers Laboratories of Korea	
	氏名	PARK, Kye-Won （朴 桂 源）	

１．研究の背景および目的

Mattress and bedding fires are a major contributor to residential fire deaths. A significant portion of these deaths and injuries results from fires in which the bedclothes are ignited, and those flames ignite the mattress or foundation. Thus, reducing bed mattress's fire risk in advance is very important to minimize residential fire casualties.

In this study, apparatus of the current ISO standard test method for measuring heat release rate of mattresses will be established, and fire risk on different size of bed mattresses will be assessed in real scale. And its results will be compared with the existing test results conducted by FILK. Reproducibility will be confirmed preliminary and reported to ISO TC92 SC1. This information provided there will be useful for making an implementation manual of the scheduled round robin test in 2013.

２．研究成果および考察（申請時の計画に対する達成度合いも含む）

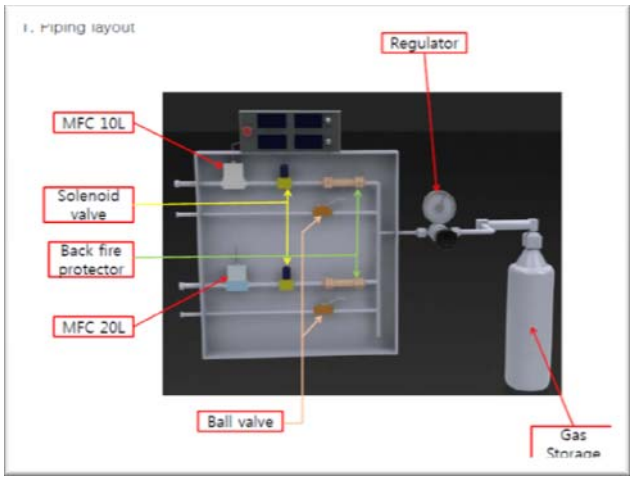
※継続課題の場合は，前年度との関係性，進展度合いについても記載すること。

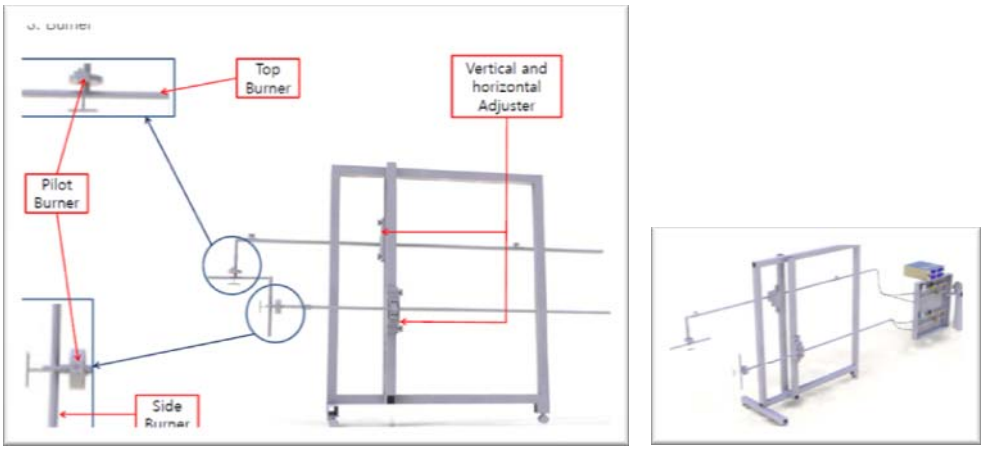
2.1) To make up the burner system as test apparatus

- Mattress burner system consisted of mainly three parts which are two pilot burners with manual ignitions, adjustable steel frame and Mass-Flow-Controller as figure 1. This system was exactly based on ISO 12949 and 16 CFR Part 1633(Consumer Product Safety Commission's standard for bed mattress test method). Burner is designed to provide LP gas automatically using Mass-Flow-Controller as described in table 1.

Table 1 Gas providing time in Burner

Burner	flow(L/min)	± (L/min)	HRR from the burner	Ignition time
Top	12.9	0.1	18 kW	70 second
Side	6.6	0.05	9 kW	50 second





Burner system design by 3D solidworks software

Figure 1 Burner system for bed mattress (entire photo : MFC photo : Burner head photo)

2.2) To select mattress specimen for the assessment

- For making test, totally six bed mattresses were selected, where there 2 kinds(one of general mattress and the other kind of fire retardant mattress) of mattresses with the size of 1 100 mm * 2 000 mm * 280 mm whose dimension is called ‘super single size’.

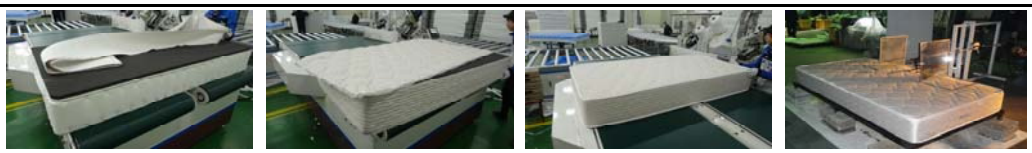


Figure 2 Example of Fire Retardant mattress's manufacturing progress

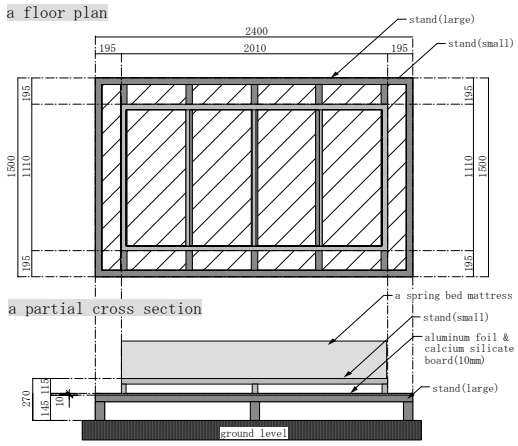
2.3) To conduct 6 cases' bed mattresses in real scale under 3MW open calorimeter

- 6 cases' bed mattresses are listed as table 2. No. 1 ~ No. 3 are FR(Fire Retardant treated) bed mattresses and No. 4 ~ No. 6 are not FR treated. Aluminum foil was used on the floor only in case of No. 1 and No. 2 with the distance from the aluminum foil to the undersurface of mattress. Aluminum foil was intended to adapt for the purpose of easily cleaning the floor in the test place. But while testing in No. 1 & No. 2, so much of the heat released from the aluminum foil has influenced on the mattress's HRR data. So, the test result has some possibility to include the heating effect from aluminum foil other than HRR of mattress itself. Therefore it has been decided to remove the aluminum foil and to secure enough space from the floor so as to prevent re-radiation heating effect from the aluminum foil.

Table 2 test condition for 6 mattresses

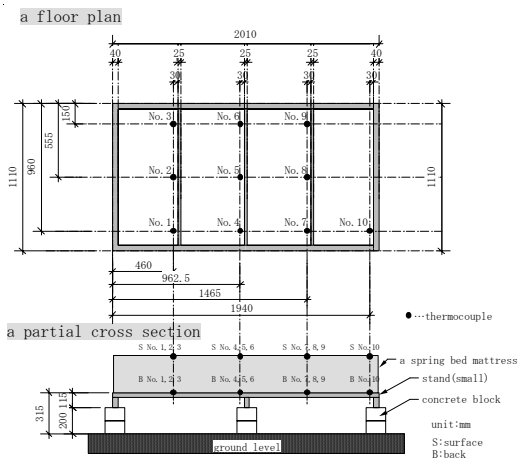
No.	設置高さ	アルミ箔	難燃処理	総発熱量	発熱速度	表面・裏面温度
	[mm]	[-]	[-]	[MJ]	[kW]	[℃]
1	115	○	○	○	○	×
2	115	○	○	○	○	×
3	315	×	○	○	○	×
4	315	×	×	○	○	○
5	315	×	×	○	○	○
6	315	×	×	○	○	×

- Basically, measurement in test were made regarding HRR(Heat Release Rate, unit of kW), THR(Total Heat Release, unit of MJ) and flame spread speed on the upper surface of mattress (unit of mm/s). In addition, temperature using thermocouples were done only in case of No. 5, No. 6 for analyzing the heat transfer effect between upper part of mattress and lower part.

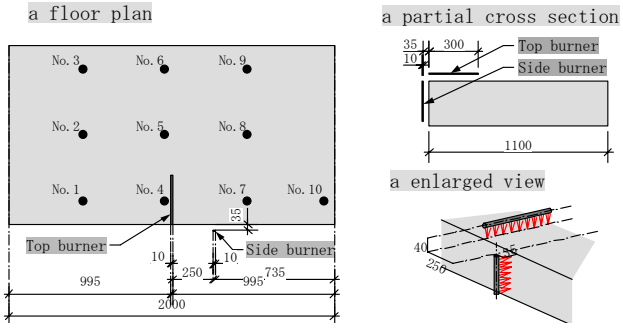


(a)　No.1,2 実験模型

(b)



(b)　No.3,4,5,6 実験模型



(c) 試験体着火位置

2.4) Result of HRR (Heat Release Rate)

- HRR data for 600s was selected for analysing as table 3 and figure 3. Normal mattress such as No. 4, 5, and 6 shows peak HRR of more than 3 000 kW in 600s. Each of them also shows FIGRA(peak HRR divided by the very elapsed time) of 12.5 kW/s, 12.2 kW/s, and 16.4 kW/s, where it means that the speed of heat release is supposed to be as rapid as of more than 10kW per second. THR(Total Heat Release) was measured of more than 350 MJ in 600s.

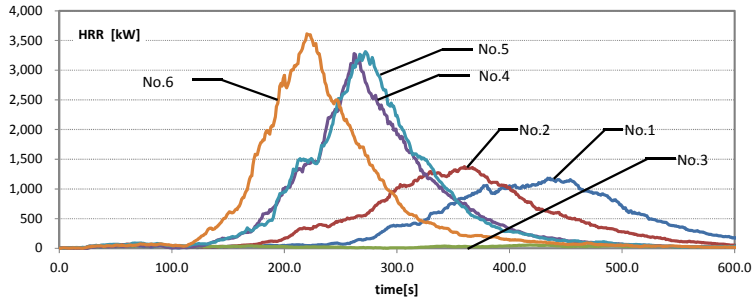


Figure 3 HRR graphs of six mattresses in 600s

- Among fire retardant mattress, No. 1 and No. 2 showed 1 180 kW and 1 374 kW respectively. These HRR value is more than twenty times of No. 3 which was peak HRR of 55.9 kW. In the review of THR, the gap is extremely deep between No.1(THR of 230.7 MJ) & No.2(THR of 249.5 MJ) and No.3(16.8 MJ).

Table 3 Results for HRR, FIGRA, and THR

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Fire retardant treatment	Yes	Yes	Yes	No	No	No
Distance *1) [mm]	115	115	315	315	315	315
Peak HRR in 600s [kW]	1 180.2	1 374.5	55.9	3 278.7	3 310.1	3 610.5
Elapsed time [s]	434.0	360.0	418.0	262.0	272.0	220.0
FIGRA [kW/s]	2.7	3.8	0.1	12.5	12.2	16.4
THR in 600s [MJ]	230.7	249.5	16.8	353.1	370.3	362.9

*1) Distance is from ground to the below surface of mattress. Only two cases such as No.1 and No 2 applied Aluminium foil on the mattress frame

- It is presumed that much higher THR result of No. 1 and No. 2 than No. 3 comes from higher heating by the melted material burning on the floor due to lower height between floor and undersurface of bed mattress, and by the re-radiation effect due to aluminum foil which is able to secure the floor of silicate calcium board against the thermal radiation from the mattress flame. Aluminum foil made the flame droplets below the mattress remain hot, and therefore magnify the total heat release. For preventing the effect of re-radiation, reflecting materials such as aluminum foil should be removed.

2.5) Result of temperature in No. 4 & No. 5

- 10 thermo couples were installed in both of mattress frame and mattress surface in case of No. 4 and No. 5 which are not of fire retardant treatment. (Measurement of temperature was focused mainly on normal mattress rather than fire retardant mattress such as No. 1, 2 and 3)

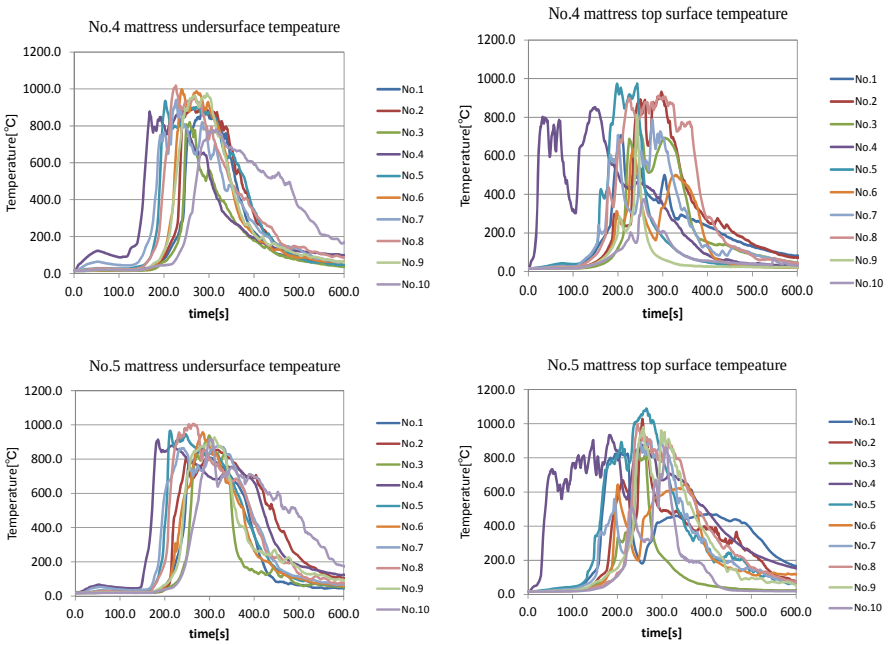


Figure 4 Temperature graph on mattress frame and mattress top surface in case of No. 4 and No. 5

- According to Figure 4, temperature on mattress frame ranges 600 ℃ to 1 000 ℃ as regularly clustered shape on the moment of around 300s. Comparatively, surfaces temperature distributes diversely depending on elapsed time. It means that opposite side from the top surface of mattress tend to accumulate heats transferred from the top surface.

2.6) Result of Flame spread speed

- The flame spread speed on the top surface is as below. No. 1's flame spread on top surface(width of 1 100 mm of mattress has reached at the opposite side in 6 minute which means the average flame spread speed of 3.1 mm/s. Results are in the table 4 as below. Mattress without fire retardant treatment such as No. 4, 5 and 6 shows very rapid average flame spread of 5.2 mm/s (on average) on top surface. Compared to No. 3(fire retardant), at best, there are 4 times of Flame spread's gap in No. 4. That means that much more of evacuation time could be given in case of fire retardant mattress compared to normal mattress.

Table 4 Results for flame speed on top surface

Case No.	Distance [mm]	Elapsed time [min:sec]	Speed [mm/s]
No. 1	1 100	6:00	**3.1**
No. 2	1 100	4:55	**3.7**
No. 3	1 100	14:54	**1.2**
No. 4	1 100	3:42	**4.9**
No. 5	1 100	3:38	**5.0**
No. 6	1 100	3:12	**5.7**

- The peak HRR is ordered as No. 6 > 5> 4>2>1>3 and the flame speed also shows the same order of No. 6>5>4>2>1>3. Therefore, the tendency of peak HRR could be identified with flame spread.

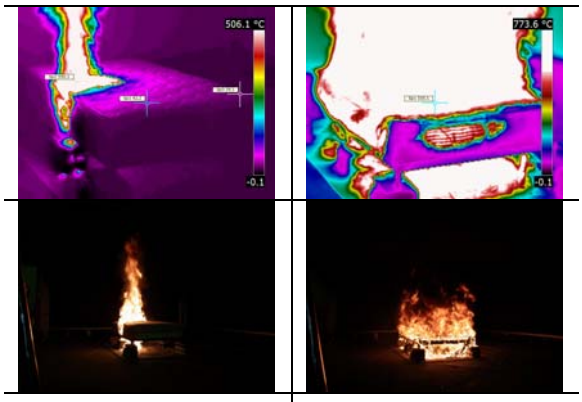
Figure 5 No. 1 photos in test(start : peak : end)

Figure 6 No. 3 photos in test(start : peak : end)

Figure 7 No. 6 photos in test(start : peak : end)

- From the moment of flame's reaching at the opposite side of top surface, whole materials of bed mattress were combusted within 2 minutes such as figure 8. Further, flame droplets below mattress

in No. 4, 5 and 6 tend to accelerate its flame spread on surface which can be said as heating effect by burning of the melted material on the floor.



2min 30sec	4min 30sec

Figure 8 Thermal transmittance situation of No. 4

2.7) Comparison result with FILK's test data

- In TUS, Non-FR mattresses such as No. 4, 5 and 6 were tested until the combustion of entire mattress without extinguishment. Meanwhile, In FILK, Non-FR mattresses were extinguished by water-suppression. Two institutes' data for Non-FR mattress is of a little limitation for comparison. But, No. 3 of TUS and FR mattresses of FILK could be made in comparison for HRR results such as peak HRR and THR as table 5.

Table 5 Results for HRR, THR in No.3 of TUS and FR 1, 2, 3, of FILK

	No. 3 of TUS	FR 1 of FILK	FR 2 of FILK	FR 3 of FILK
Fire retardant treatment	Yes	Yes	Yes	Yes
Distance *1) [mm]	315	315	315	315
Peak HRR in 600s [kW]	**55.9**	**58**	**47**	**43**
Elapsed time [s]	418.0	80	72	89
FIGRA [kW/s]	0.1	0.72	0.65	0.48
THR in 600s [MJ]	**16.8**	**18.6**	**13.7**	**13.9**

- Peak HRR on average of FILK's FR 1, FR 2 and FR 3 is 49.3 kW and, THR on average is 15.4 MJ. Compared to No. 3 of TUS's peak HRR (55.9 kW), there is the peak HRR's gap of 6.6 kW. With respect to THR, there has the gap of 1.4 MJ between No. 3 of TUS and the average THR of FILK. Generally, it could seem that such gap regarding HRR & THR would not be of so much difference in real scale test trial.

2.8) Summary & Discussion

- Normal bed mattress without any fire retardant treatment is of peak HRR of more than 3 MW before 300s. It is suggestive the fact that Once normal bed mattress is ignited, only a few minutes are allowable for evacuation of occupants. Therefore, it's very important to prevent the ignition of bed mattress, otherwise adapt the fire retardant bed mattress in residential house.
- When trying ISO 12949, Aluminium foil should not be adapted on the floor since it may influence the HRR result such as re radiation of HRR. In this experiment, enough distance (i.e, 315 mm) from the ground to mattress is recommended for the purpose of preventing heating effects from the flame droplet on the floor.
- Concerning flame spread's speed, No. 3(FR mattress) shows the latest speed of 1.2 mm/s, while No. 6(without FR treatment) was the fastest of 5.7 mm/s. That means that much more of evacuation time could be given in case of fire retardant mattress compared to normal mattress.

4) Order of HRR has an agreement of flame spread in order in six cases' mattress. This implies that HRR index can replace of flame spread, even HRR could be modified into THR and FIGRA. Measurement of HRR could be said to be very important, useful, and informative in the reaction-to-fire test of bed mattress.

- Compared to FILK's test data, peak HRR shows the gap of 6.4 kW and THR's gap of 1.4 MJ between two institutes' test data.

2.9) providing some information of ISO round robin toward ISO TC92 in 2013

- On April 10th, 2013, ISO TC92 SC1 (Fire safety – fire initiation & growth) meeting was held in DIN, Germany. I attended at the WG7 meeting and made presentation for ISO Round Robin status in 'Any Other Business session' of WG7, where the current bed mattress RRT's schedule and participant institutes were introduced. I also requested that this RRT should be under preliminary New Working Item Proposal at WG7. ISO members made agreement on my suggestion. So, If some meaningful result from this RRT comes out, this RRT item seems to be under prliminary NWIP from next ISO meeting.

※スペースが足りない場合はページを増やしても構いません。

３．経費の使用状況

消耗品費・会議費・印刷費等		旅　　費		人　件　費	
事　　項	金額(千円)	事　　項	金額(千円)	事　　項	金額(千円)
ベッド燃焼実験用テストフレーム・架台	194				
燃焼用ベッドマットレス	306				
計	500	計		計	

４．今後の展望（今後の発展性，見込み等についても記述）

- This was the first trial for bed mattress fire test based on ISO 12949.
- In future, heat effect on compartment space from the bed mattress could be conducted and through this experiment, the critical HRR from the bed mattress which can be influenced to the big damage(i.e flashover phenomenon) of a room would be checked in overall point of view. Further, such information is able to provide to save evacuation time for occupants in building environment.
- With respect to ISO TC92 SC1, it seems that RRT for bed mattress is progressing without any problem and this autumn, thus some useful test data from each participant institute would come up. Therefore, Precision data(analytical) and some useful notice for making test through this RRT could be reflected to ISO 12949 standard.

５．成果の公表状況（学会への発表，学術誌への投稿等を記述。予定も含む）

1) Kye-Won PARK, Woon-Hyung KIM, Yoshifumi Ohmiya, “Research for assessment on real scale bed mattress in fire”, 2012 International Conference on Fire Science and Disaster Management, October of 2012, Taiwan, 3-1~3-7p.

2) Kye-Won PARK, “Assessment of Flame spread on Bed mattress through Reaction-to-fire analysis”, 2012 SSS(Society for standards and standardization) autumn conference of Korea, Oct. 11th of 2012, 328~335p.

3) Kye-Won PARK, “Description of measurement module for reaction-to-fire index on real scale bed mattress”, 2012 SSS(Society for standards and standardization) autumn conference of Korea, Oct. 11th of 2012, 623~627p.

4) Kye-Won PARK, Jae-gun JEONG, “Correlation analysis on HRR & SPR on real scale bed mattress’s fire test”, 2012 Proceeding of Fall annual conference of Korean Institute of Fire Science & Engineering, Nov. 15th of 2012, 149~152p.

5) Kye-Won PARK, Jae-gun JEONG, “Experimental study on the reaction-to-fire performance of bed mattress in real scale”, 2012 Proceeding of Spring annual conference of Korean Institute of Fire Science & Engineering, May 3rd of 2012, 38~42p.

6) Kye-Won PARK, Jae-gun JEONG, “Description on assessment system of bed mattress’s fire safety in real scale”, 2012 Proceeding of Spring annual conference of Korean Institute of Fire Science & Engineering, May 3rd of 2012, 329~332p.

7) Kye-Won PARK, Jae-gun JEONG, “Study on Fire safety test method for the bed mattress”, 2012 Proceeding of Spring annual conference of Korean Institute of Fire Science & Engineering, May 3rd of 2012, 325~328p.

8) 木村和貴, Kye-Won Park, 大宮喜文, 水野雅之, “ISO 12949に基づいたベッドマットレスの燃焼実験　その1　研究背景と実験手法 “, AIJ, August of 2013, (expected)

9) Kye-Won PARK, Kazutaka Kimura, Yoshifumi Ohmiya, Masayuki Mizuno , Yoshihiko Hayashi, “Combustion Experiment of bed Mattress based on ISO 12949: Part 2 – results & discussion from real scale fire test”, AIJ, August of 2013, (expected)

10) Kye-Won PARK, Jae-Gun JEONG, “Study on Uncertainty of HRR for real scale bed mattress’s fire test”, April 18th of 2013, 103~104p.

※上記５に記載された成果公表については，別刷１部を研究事務課まで提出願います。PDF ファイル等の電子データでも構いません。
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