
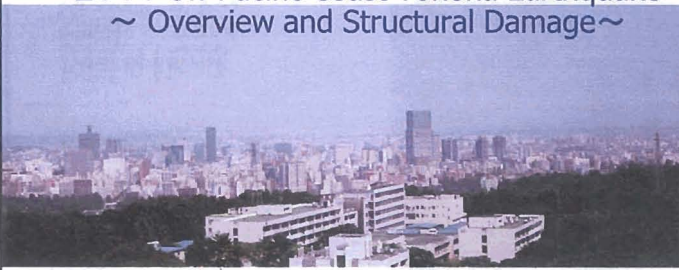




UNAM Briefing 2011/06/23



2011 Off Pacific Coast Tohoku Earthquake
~ Overview and Structural Damage ~





TOHOKU UNIVERSITY
DISASTER CONTROL RESEARCH CENTER
Masato MOTOSAKA



Contents (I)


- General Information on the earthquake and damage
- Ground motion characteristics in Sendai Area
 - * Comparison of 1978 Eq. at same obs. Pt.
 - * Site effects based on DCRC observation network
 - hilly zone (eq. Aobayama Campus)
 - alluvial deposit (eq. Oroshimachi)
 - deep underground structure of Sendai Basin



Contents (II)

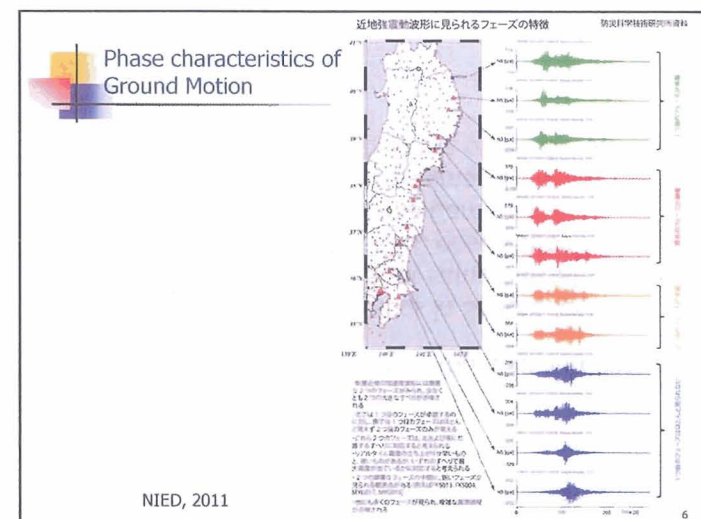
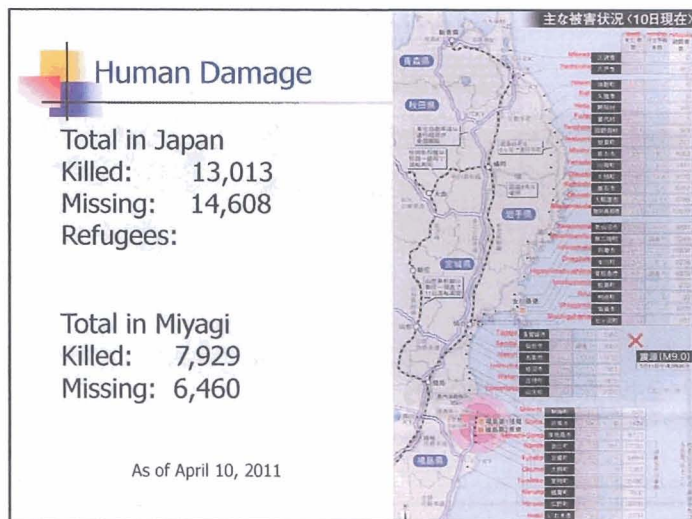
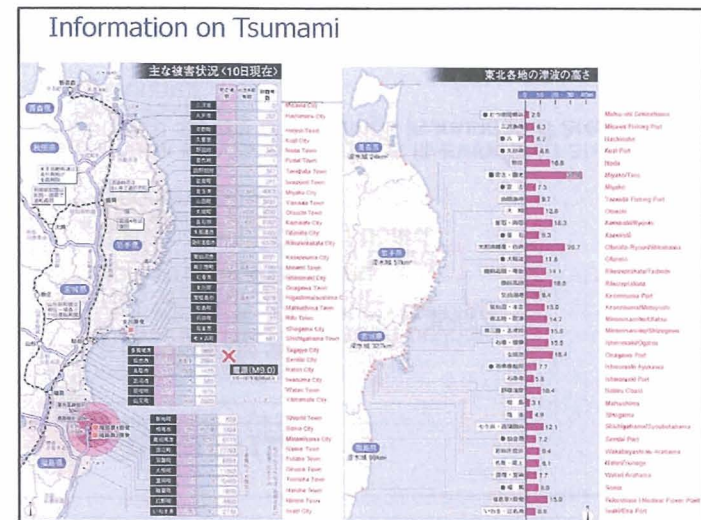
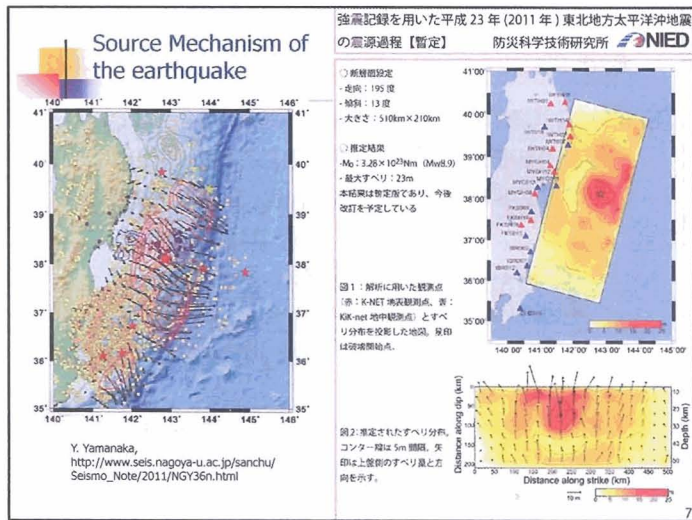
- Quick Damage Survey :
 - * Sendai City : Damaged Area and Buildings during 1978 Miyagi-ken Oki earthquake + inundated area by tsunami
 - * Osaki City & Kurihara City : Damaged area during the 2008 Iwate-Miyagi Nairiku Eq.
 - * Damaged Area during 2003 Northern Miyagi Eq.

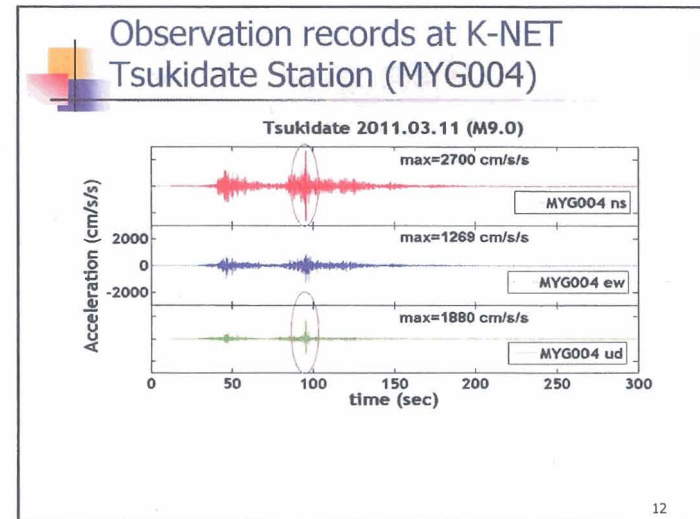
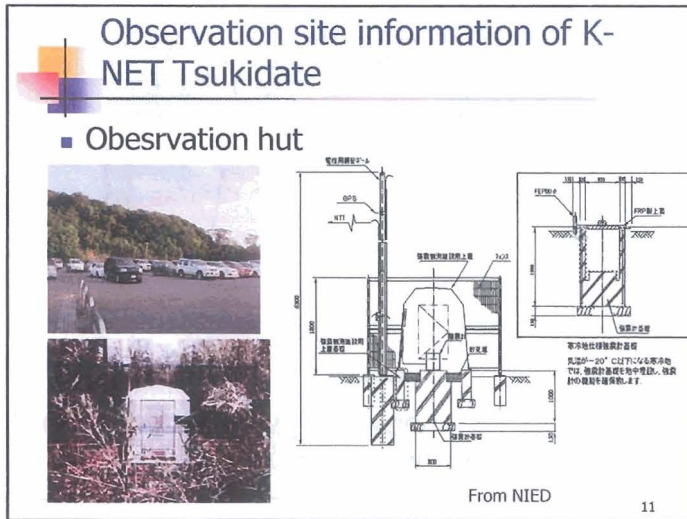
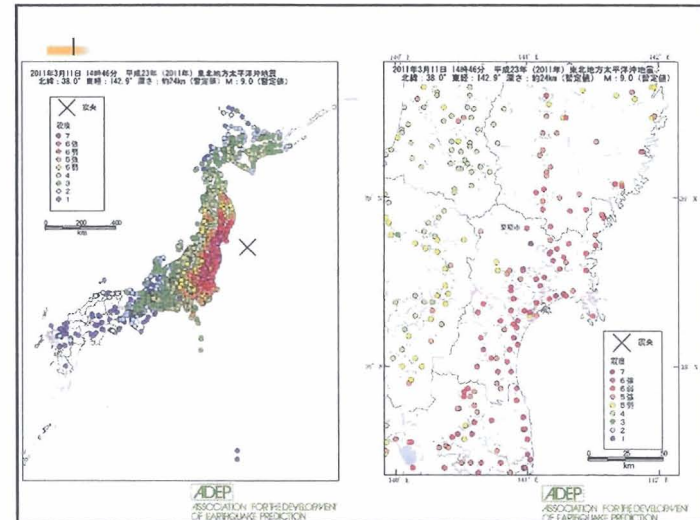
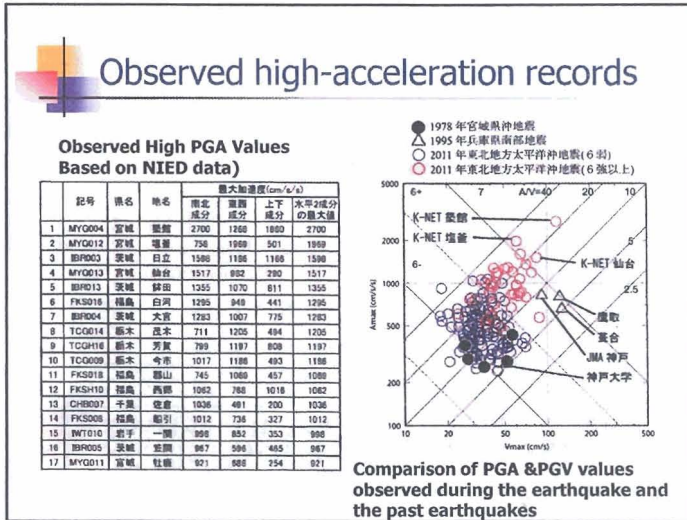
The huge earthquake attacked the damaged area due to past earthquakes !

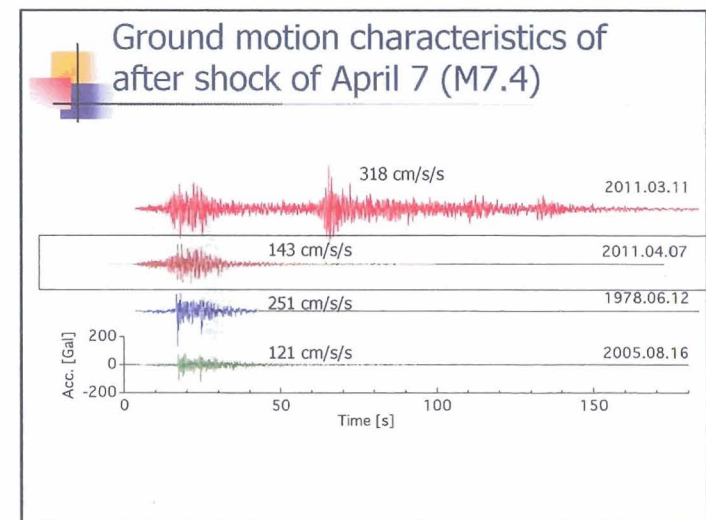
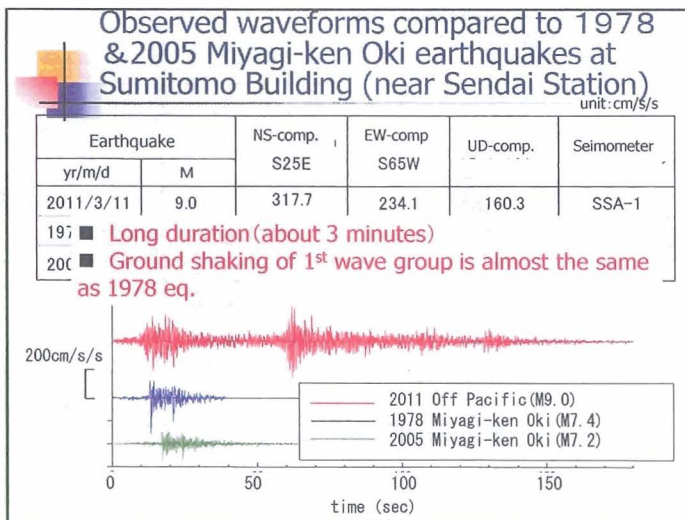
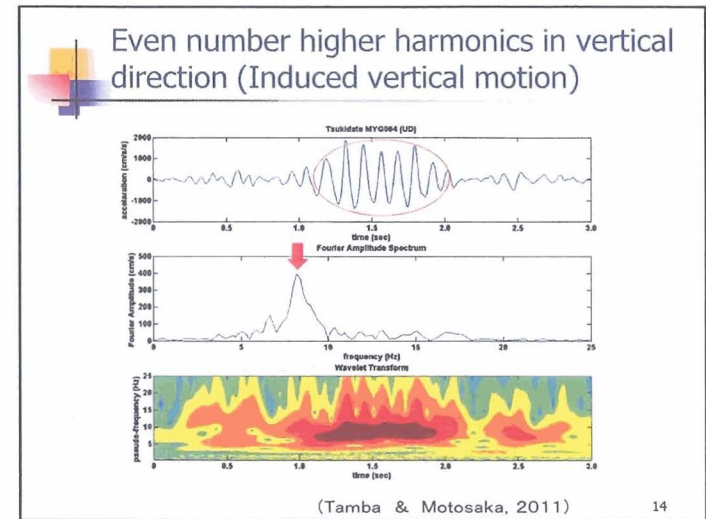
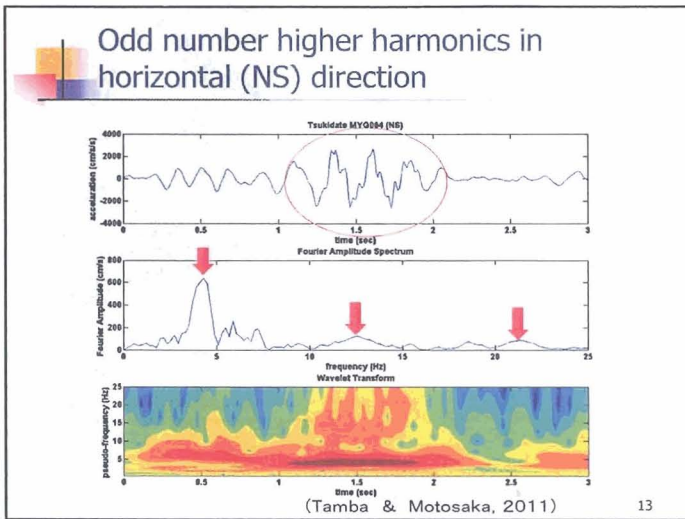


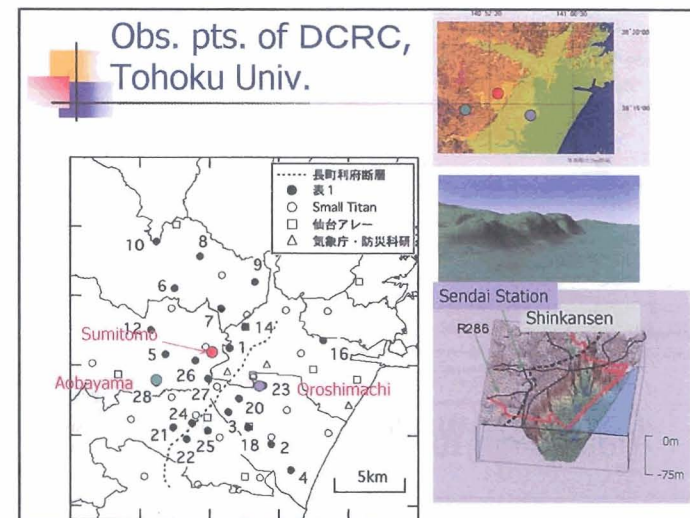
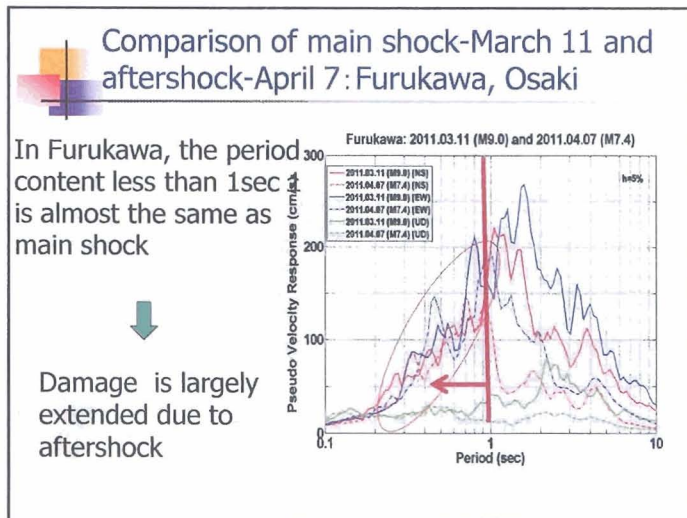
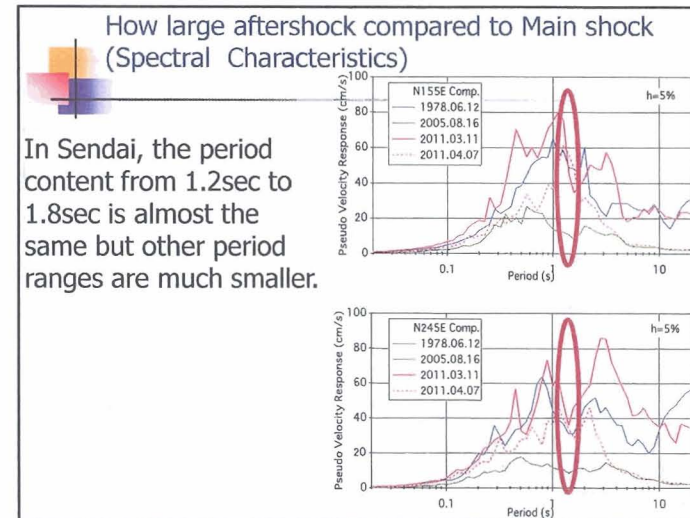
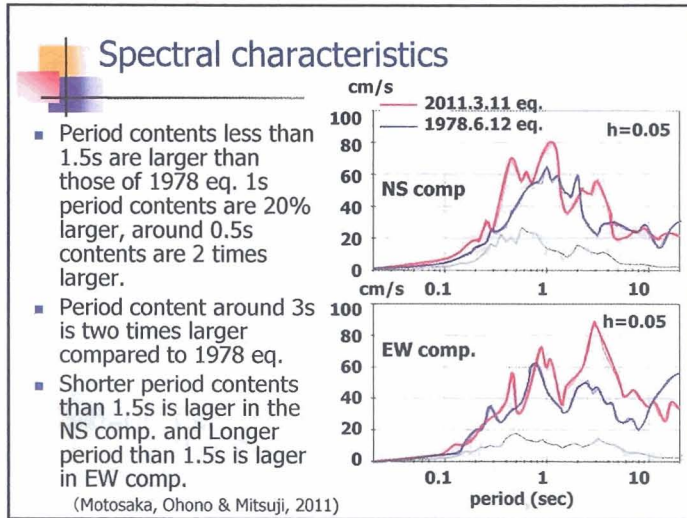
Contents (III)

- Specific damage survey
 - * Damaged Pile foundation building
 - * Non-structural elements
 - External wall, Ceiling board
 - * Wooden houses
- Damage survey of buildings in inundated area by tsunami









PGA & PGV of Observation data ~ DCRC, Tohoku University network

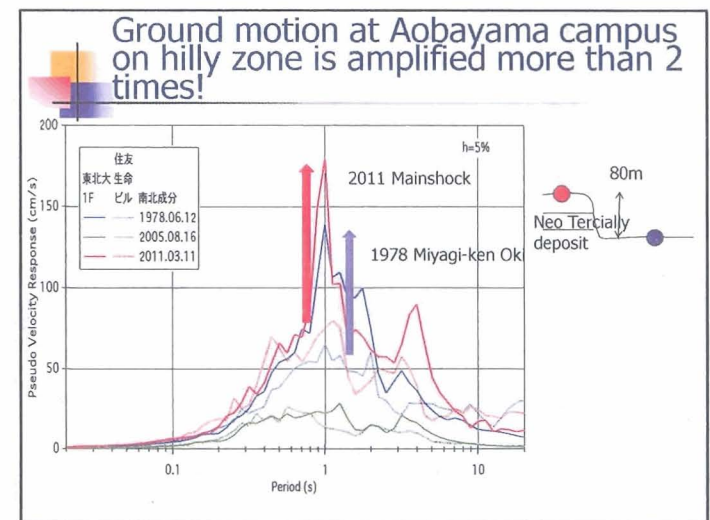
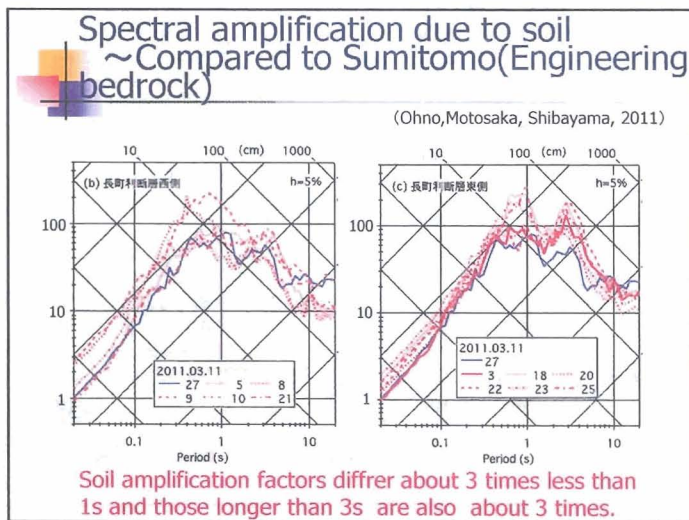
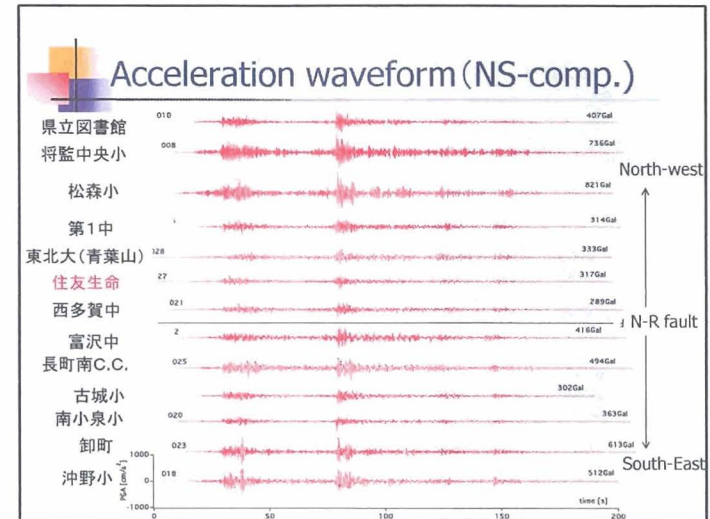
Max.
Acc.(PGA)
300cm/s/s~
800cm/s/s

Max.
Vel.(PGV)
30cm/s~
80cm/s

(Ohno, Motosaka,
Shibayama,2011)

No	地震計	地点名	2011/4/7			2011/3/11			2011/3/9		
			PGA (cm/s ²)	PGV* (cm/s)	計測 震度	PGA (cm/s ²)	PGV* (cm/s)	計測 震度	PGA (cm/s ²)	PGV* (cm/s)	計測 震度
2	ETNA	六郷小	311	42.1	5.7	欠測	欠測	欠測	欠測	欠測	
3	ETNA	古郷小	251	22.4	5.1	320	61.3	5.6	24	3.1	3.2
4	ETNA	東六郷小	欠測	欠測	欠測	613	74.2	5.9	29	3.4	3.4
5	QDR	第一中	230	19.3	5.1	383	41.5	5.6	28	2.9	3.4
8	QDR	将監中央小	534	25.3	5.5	840	64.2	6.0	30	2.2	3.2
9	QDR	松森小	767	75.5	6.2	822	88.2	6.4	46	4.2	3.6
10	QDR	宮城県立図書館1F	279	18.0	4.9	407	65.0	5.5	20	2.4	3.1
11	QDR	宮城県立図書館3F	欠測	欠測	欠測	欠測	欠測	欠測	34	3.1	3.5
12	QDR	仙台青森中等教育学校1F	欠測	欠測	欠測	欠測	欠測	欠測	19	3.5	3.3
14	QDR	鶴谷小学校1F	432	30.6	5.6	欠測	欠測	欠測	20	1.9	3.0
16	QDR	中野小学校1F	欠測	欠測	欠測	欠測	欠測	欠測	40	3.2	3.5
18	QDR	沖野小学校1F	360	31.8	5.5	512	79.4	6.1	37	3.5	3.5
20	QDR	南小泉小	220	25.7	5.2	381	63.7	5.5	19	2.4	3.1
21	QDR	西多賀中	186	16.4	5.0	400	47.3	5.5	23	3.0	3.4
22	QDR	富沢中	232	21.1	5.1	416	57.9	5.7	29	3.2	3.3
23	QDR	富沢水管理事務所	472	37.3	5.7	613	77.0	6.1	30	2.6	3.2
24	QDR	湯沢寺	欠測	欠測	欠測	欠測	欠測	欠測	欠測	欠測	欠測
25	QDR	長町南コミュニティセンター	264	29.5	5.5	494	68.3	5.9	59	6.0	4.0
26	QDR	青葉区役所	318	21.9	5.1	欠測	欠測	欠測	24	3.2	3.2
27	SSA-1	住友生命ビル	167	14.0	4.9	318	30.0	5.3	15	2.2	3.1
28	SMAC-MD	東北大学1F	欠測	欠測	欠測	333	59.8	5.6	35	4.4	3.6



*カブト型周長10秒 *カブト型周長50秒



Damage to 9 story SRC building at Aobayama campus

Reasearch Building of Department of C.E & A-B.S Eng.

1969 Completion
1978 Earthquake
2000 retrofit
2005 Earthquake
2008 Earthquake






Ground motion at around 1s period content is amplified two times

Strong motion records shows:

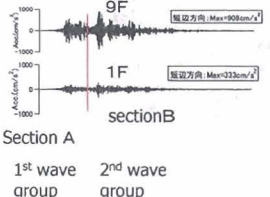
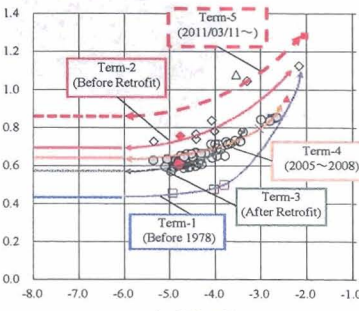
Max Acc. Of NS-comp.
1F: 333cm/s/s
9F: 908cm/s/s

4 corner external columns are damaged heavily at their bottom

Change of natural period of the building for about 40 years after completion

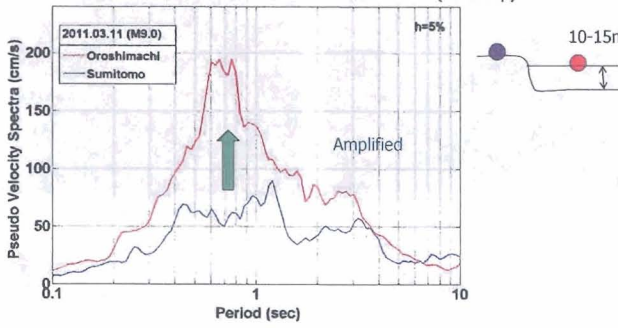
(Motosaka et al. 2011)

Relation of natural period and deflection angle (TR direction)

Site Effect ~ Alluvial Deposit: Oroshimachi

Oroshimachi (NS) and Sumitomo Building (N155E, (NS comp))



2011.03.11 (M9.0)

h=5%



10-15m

Amplified

Damage of RC building in alluvium site in Oroshimachi

Max.Acc.=613 cm/s/s

Construction year 1969 Construction year 1969


Collapse of 2 story RC building at Oroshimachi 2 chome

Collapse of 3 story RC building at Oroshimachi 3 chome

Damage of RC building in alluvium site in Yamato-machi ~Collapse of 3 story RC building

Effect of torsional motion

PGA: about 600cm/s/s



Construction year before 1981

Yamato-machi 5 chome

Damage of pile foundation buildings

Damage of pile-foundation building condominium building in Takasago

Inclination angle: 1/100

Inclination angle: 1/56

Increased to 1/45 due to after shock



inclined

14 story SRC building

Completion: 1976

Damaged building during 1978 earthquake

Pile length: 24m

Pile foundation building ~ Nagamachi Kohriyama Municipal Apartment Building

no residual displacement was observed at the expansion joint



This building showed the trace of rocking motion, and cracking was observed in the ground along the base.

This building was tilted attributable to the damage in piles after the 1978 Miyagi-ken Oki Earthquake

No damage

Damaged building during the 1978 Miyagi-ken Oki earthquake

Inclined RC building in Oroshimachi Damage of piles



Construction year: 1983
Pile length: 26m

Furukawa West J.H.S., Osaki City



Inclined angle: 1/30

Foundation damage of RC building



11階建ホテルの基礎部の傾斜

Damage of Non-structural Elements

- Drop of Ceiling Board
 - * hanging type ceiling board
- External wall of steel structure

Fall of Ceiling Board of Space Structure ~ 仙台メディアテーク



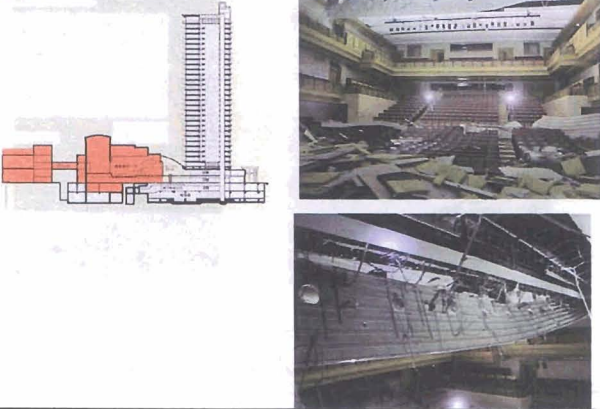
Ceiling board of 7th floor (Top floor) was dropped 60% during main shock And the remaining 40% was dropped during April 7 aftershock

Fall of ceiling board of large span building ~ Sendai Media-Take(7 story SRC)



Suspension type ceiling board; 60% during main shock and the remaining 40% during after shock

Fall of ceiling board Hall of Taihaku-ku Culture Center, Sendai



Drop of Ceiling board of municipal assembly rooms ~ Kurihara City Hall



Drop of Ceiling board of municipal assembly rooms~Shiroishi City Hall



Damage of non-structural elements



Fall of exterior wall of steel structure (Oroshimachi)

Fall of External walls

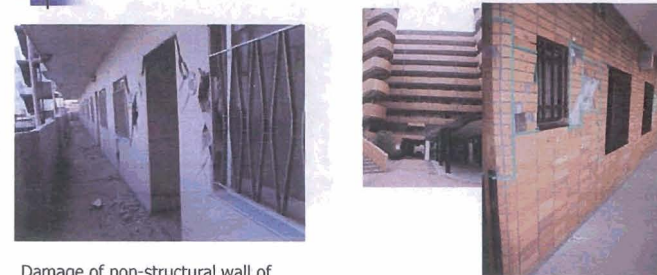


Exterior finishing fell from a two-story steel building

Fall of roofing materials from a two-story steel building

Detail of fastener (anchor) of failed ALC exterior wall

Damage of Non-structural element of RC buildings



Damage of non-structural wall of 14 story RC building in Yamato-machi, Sendai

Damage of non-structural wall of 10 story RC building in Kashiwagi-machi, Sendai

Damage of Wooden houses

- old and damage experienced houses
- housing lands failure

Damage of wooden structure(I)



土蔵の倒壊

Old houses on alluvial site



木造2階建て店舗の倒壊

Damage of wooden structure(II)



木造校舎の被害(古川第1
小学校)




倒壊した木造建物

Housing land failure



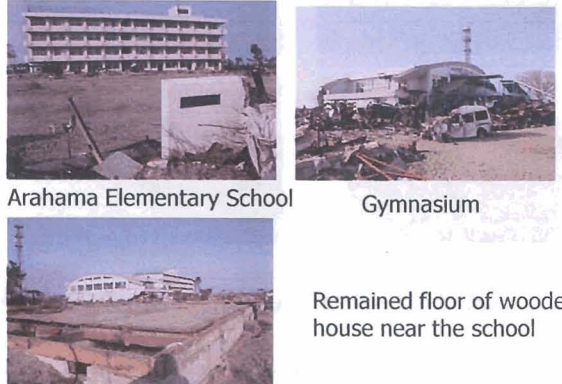
Damage survey of buildings in inundated area by tsunami

Shopping Mall and Convention Center (Yume Messe Miyagi)



The images show extensive damage to the Yume Messe Miyagi shopping mall and convention center. The top-left photo shows a large pile of debris and a collapsed structure. The top-right photo shows an interior view of a damaged atrium. The bottom-left photo shows the exterior of the building with significant structural damage. The bottom-right photo shows a large piece of machinery or equipment that has been crushed and overturned.

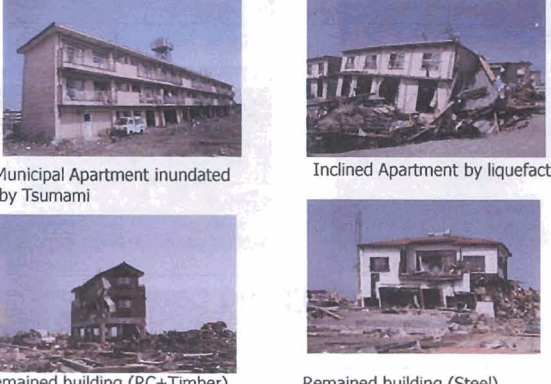
Arahama Area ~inundated area by Tsumami



Arahama Elementary School Gymnasium

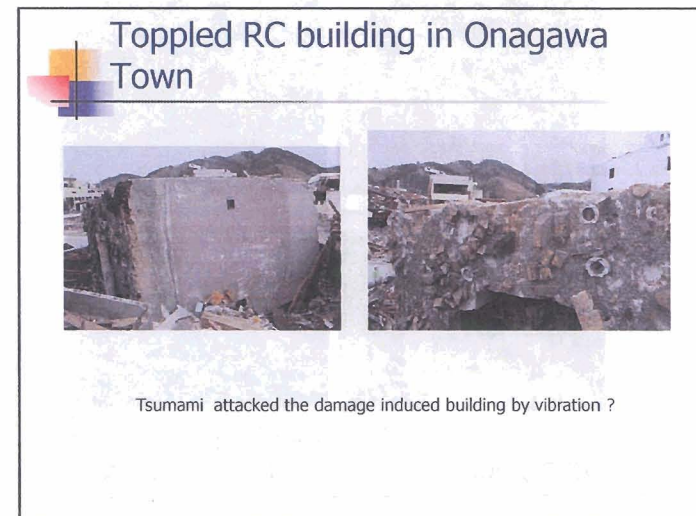
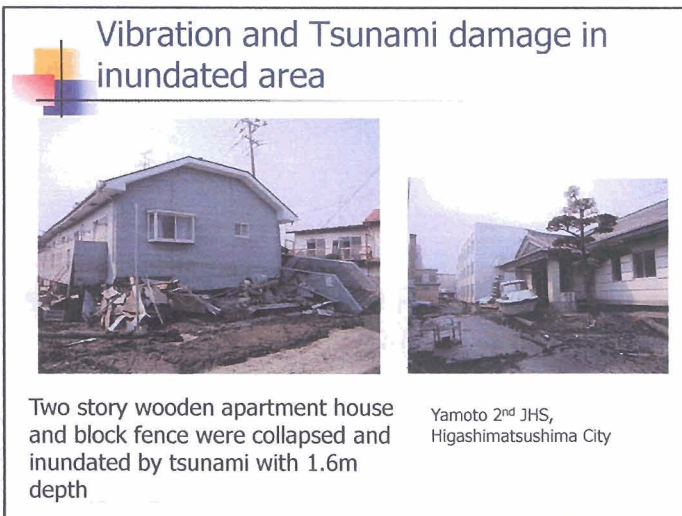
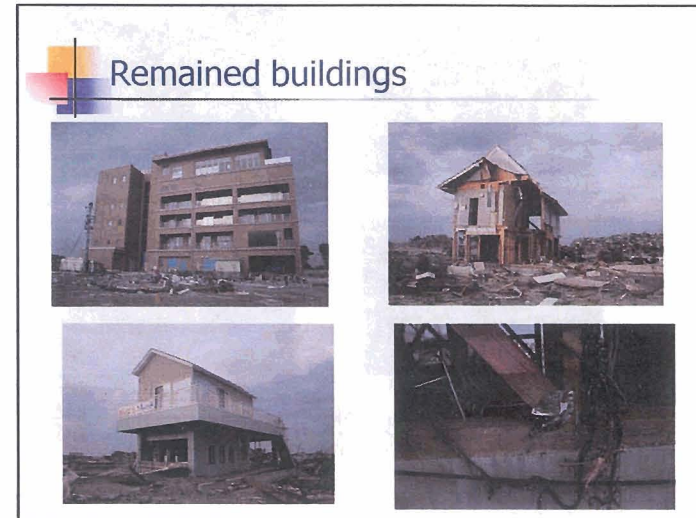
Remained floor of wooden house near the school

Yuriage Area, Natori City



Municipal Apartment inundated by Tsumami Inclined Apartment by liquefaction

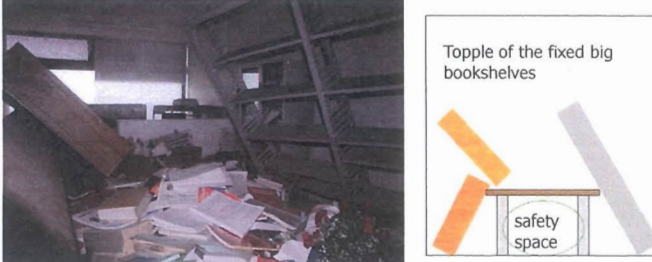
Remained building (RC+Timber) Remained building (Steel)



Concluding Remarks

- Remarkable damage difference due to soil conditions
 - * Necessity of appropriate microzoning
- Appropriate remaining seismic resistant capacity of the damaged building due to past earthquake
 - * Necessity of damage inspection for pile-foundation building
- Effectiveness of reinforced part but the surrounding remaining part
- Relation of observed high-acceleration records and structural damage
 - * appropriate ground motion index for structural damage

End~secure safety space in your surroundings !



Prof. Motosaka's office after the 3.11 earthquake

Saved from severe shaking due to Earthquake Early Warning and Big table !

Topple of the fixed big bookshelves

*Surging 'Book wave' due to vibration with 3 minutes duration
*Inside-open door blocked to escape

Thank you for your attention!