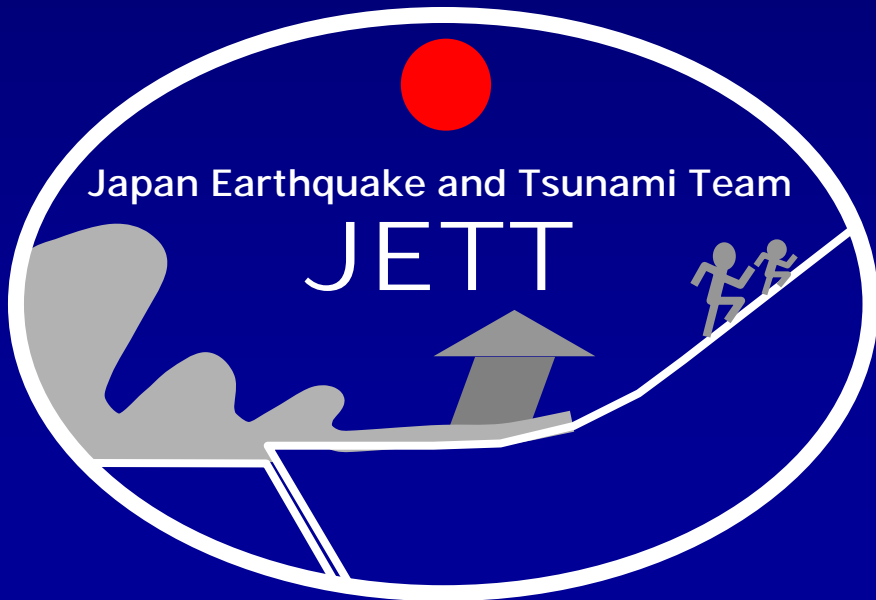
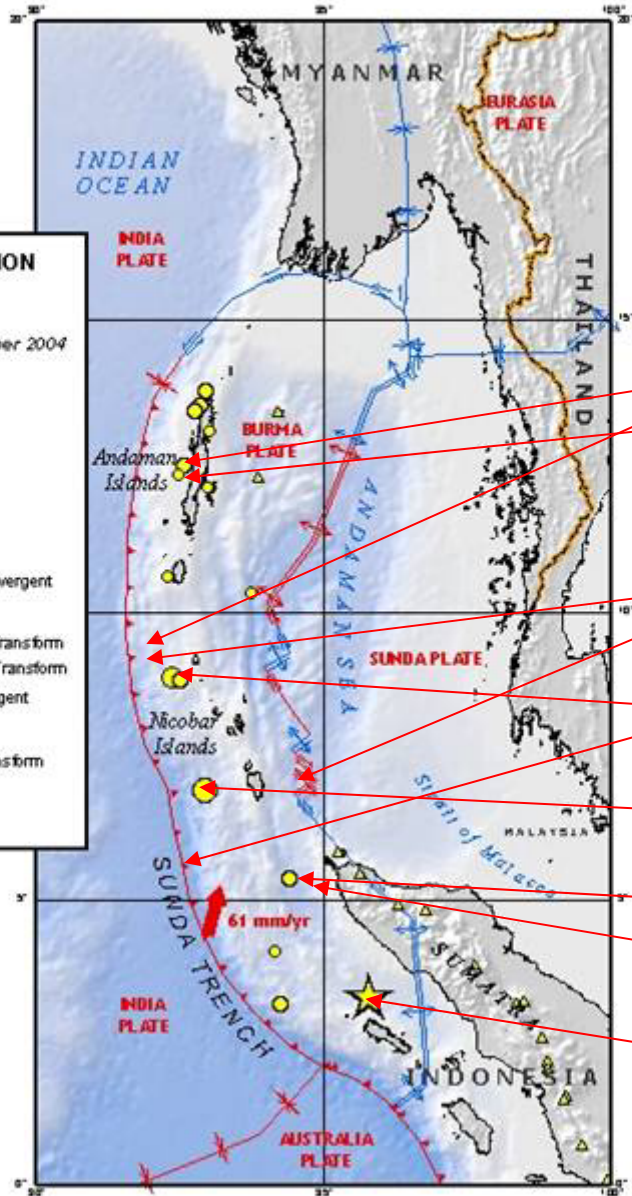


アンケートによるバンダアチェの 震度・津波の評価



家村浩和・高橋良和・
本田利器・
Mulyo Harris Pradono
(京都大学)
Rudi Kurniawan
(Syiah Kuala University)

M9.0 Andaman - Nicobar Islands Earthquake of 26 December 2004



EXPLANATION

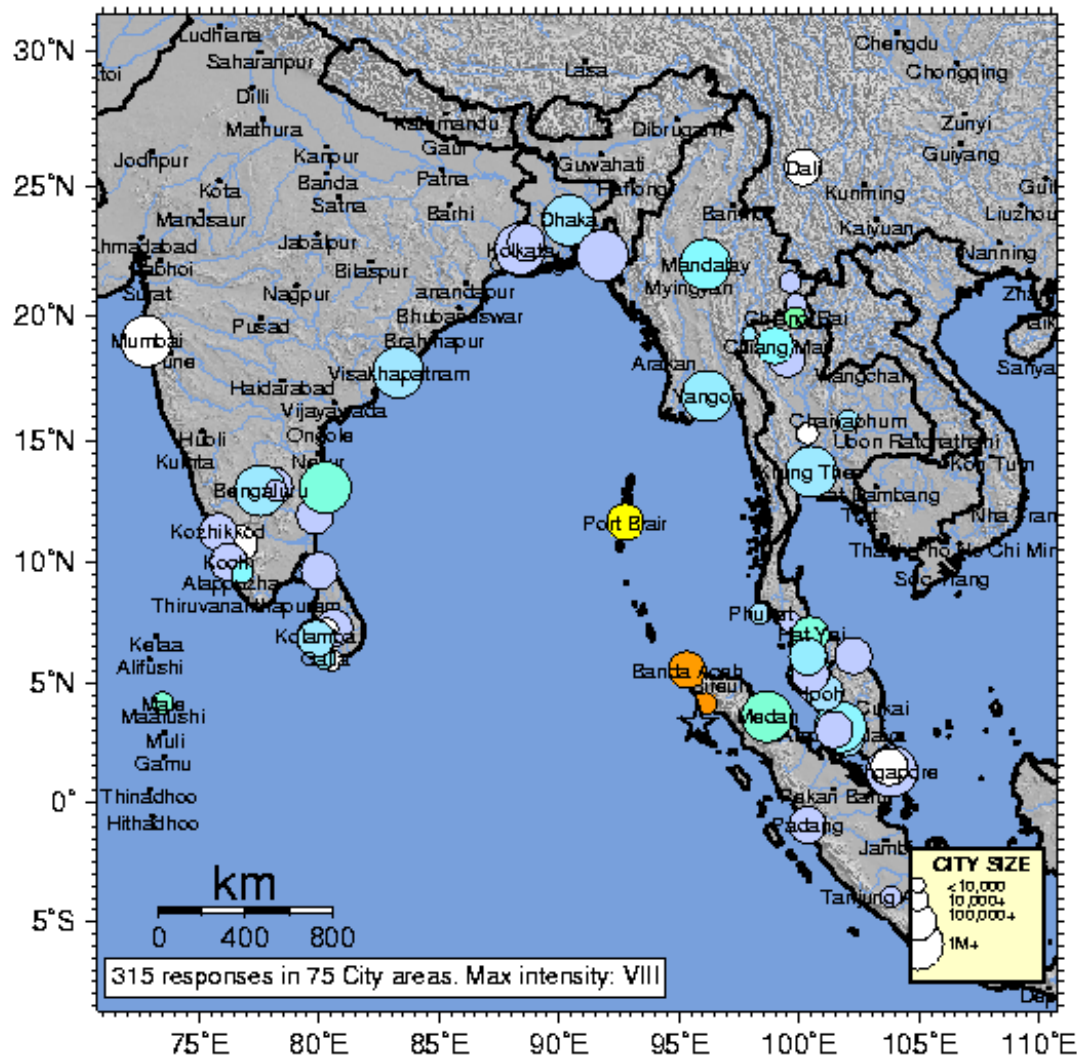
Main Shock
 26 December 2004

Aftershocks
 5.70 - 5.90
 5.91 - 6.40
 6.41 - 6.90
 6.91 - 7.30

Plate Boundaries
 Continental Convergent
 Continental Rift
 Continental LL Transform
 Continental RL Transform
 Oceanic Convergent
 Oceanic Rift
 Oceanic RL Transform
 Subduction
 Volcanoes

Main Earthquake and Sequence of Aftershocks

- 02:22:01UTC **M5.8** 8.85N 92.42E
- 02:15:59UTC **M5.7** 12.33N 92.48E
- 02:15:50UTC **M5.3** 12.10N 92.19E
- 02:00:40UTC **M6.0** 6.83N 94.61E
- 01:59:14UTC **M5.5** 8.37N 92.43E
- 01:40:07UTC **M5.5** 5.76N 93.03E
- 01:22:27UTC **M6.0** 7.68N 93.72E
- 01:21:26UTC **M6.1** 6.36N 93.35E
- 01:25:49UTC **M6.0** 5.54N 94.17E
- 01:48:49UTC **M5.8** 5.40N 94.42E
- 00:58:53UTC **M9.0** 3.31N 95.55E



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

Intensities

The earthquake was felt (VIII) at Banda Aceh and (V) at Medan, Sumatra. It was felt (II-IV) in parts of Bangladesh, India, Malaysia, Maldives, Myanmar, Singapore, Sri Lanka, and Thailand. Subsidence and landslides were observed in Sumatra

Source: USGS Earthquake Hazard Program
<http://neic.usgs.gov/eqinthe news/2004/usslav>

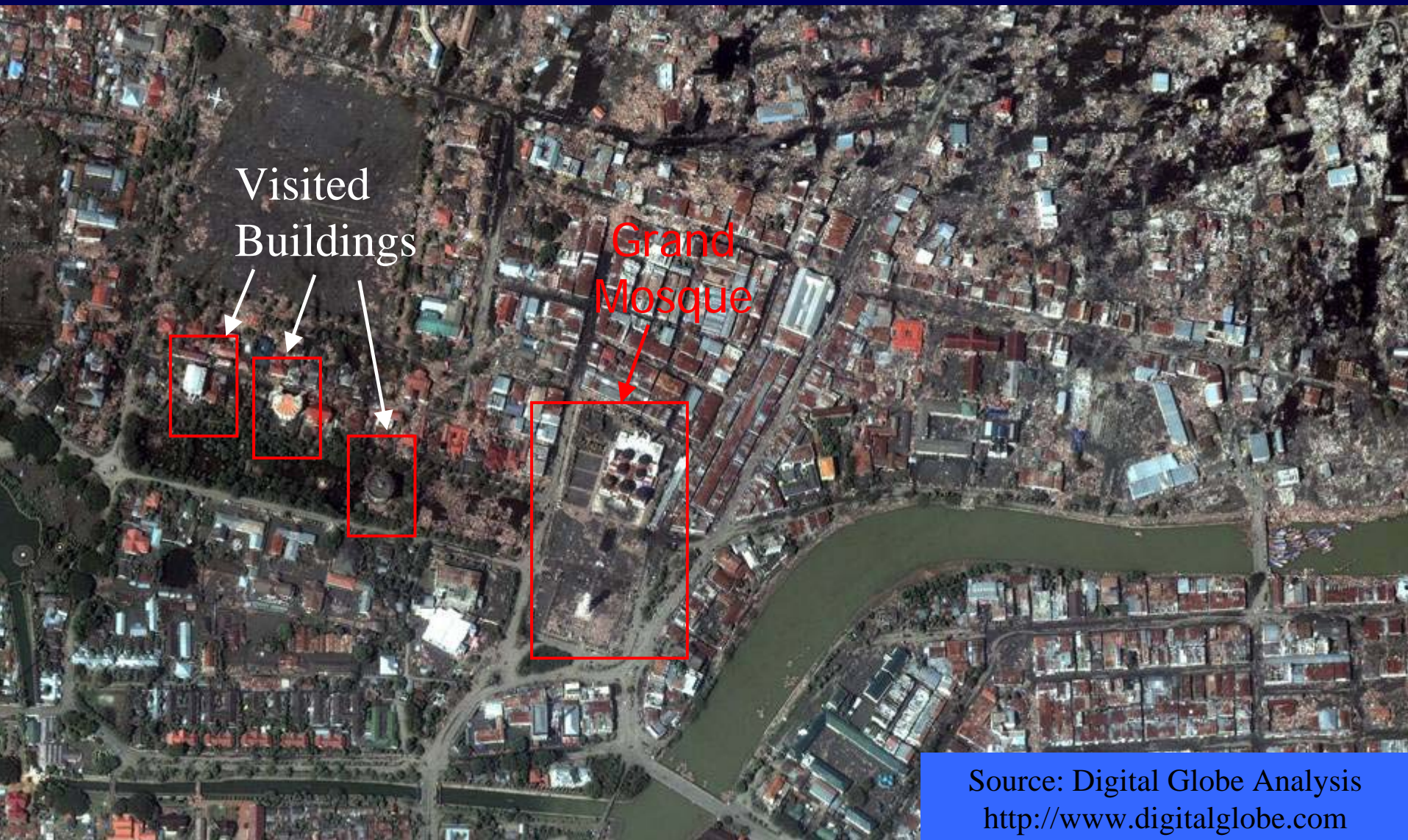
Source: Digital Globe Analysis
<http://www.digitalglobe.com>

Banda Aceh, Indonesia



Buildings Near Grand Mosque

Satellite Photo December 28, 2004



Baiturrahman Grand Mosque

Survey March 02, 2004

Main Tower
(east of main build.)



Tsunami
flood about
80 cm

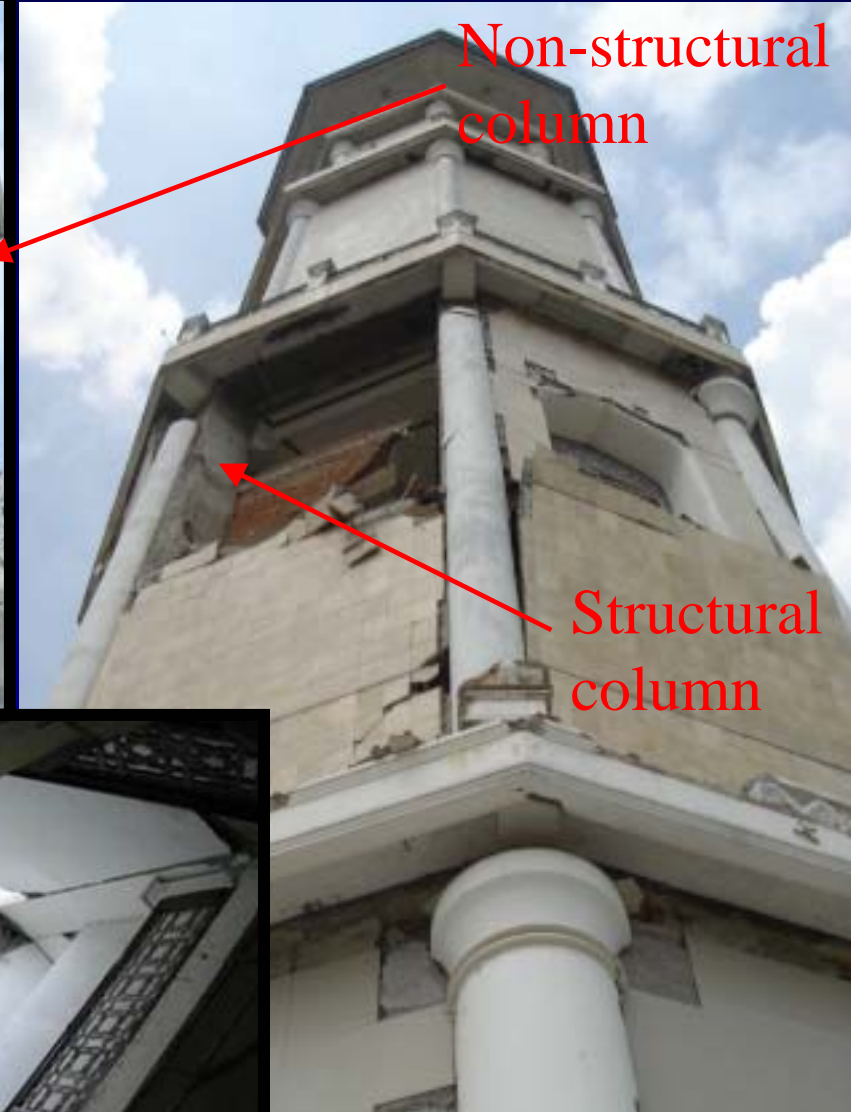


Severe
cracking
and spalling
of concrete



Baiturrahman Grand Mosque

Survey March 02, 2004



Baiturrahman Grand Mosque

Survey March 02, 2004

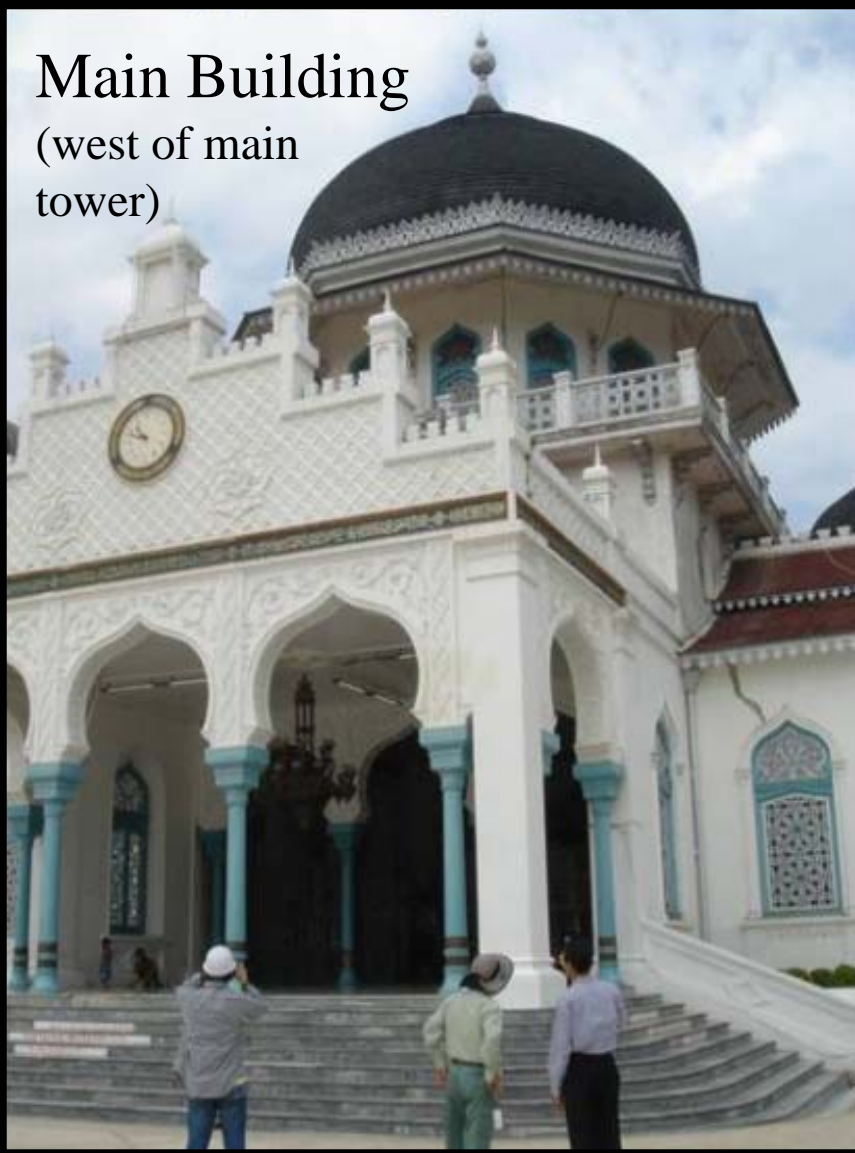


Elevator structure
inside the tower

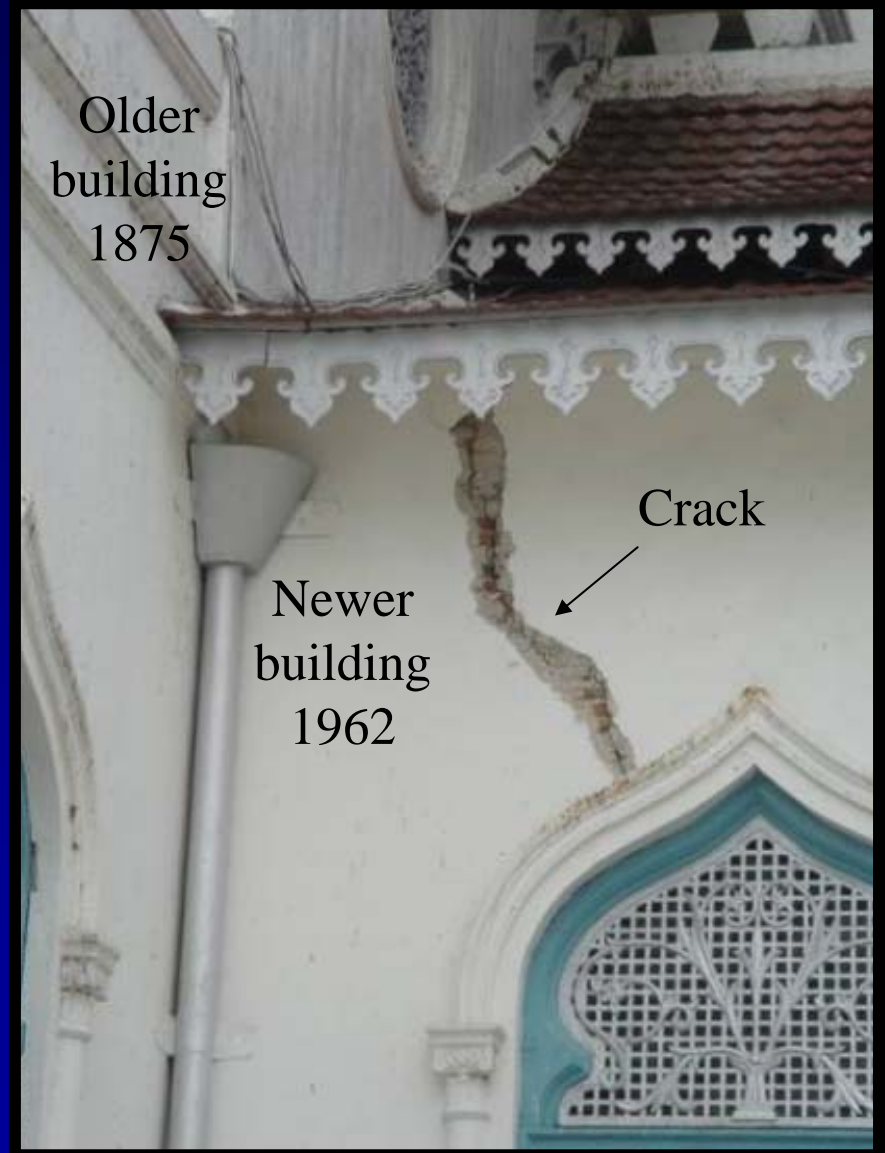
Baiturrahman Grand Mosque

Survey March 02, 2004

Main Building
(west of main
tower)



Older
building
1875



Newer
building
1962

Nearby Buildings

March 02, 2005



Nearby Buildings March 02, 2005 (Kuala Tripa Hotel)

The hotel was expanded from a
4-story hotel to a 5-story hotel



Nearby Buildings March 02, 2005 (Kuala Tripa Hotel)

After the earthquake, one
lower story was collapsed



Nearby Buildings March 02, 2005 (Water Tower)



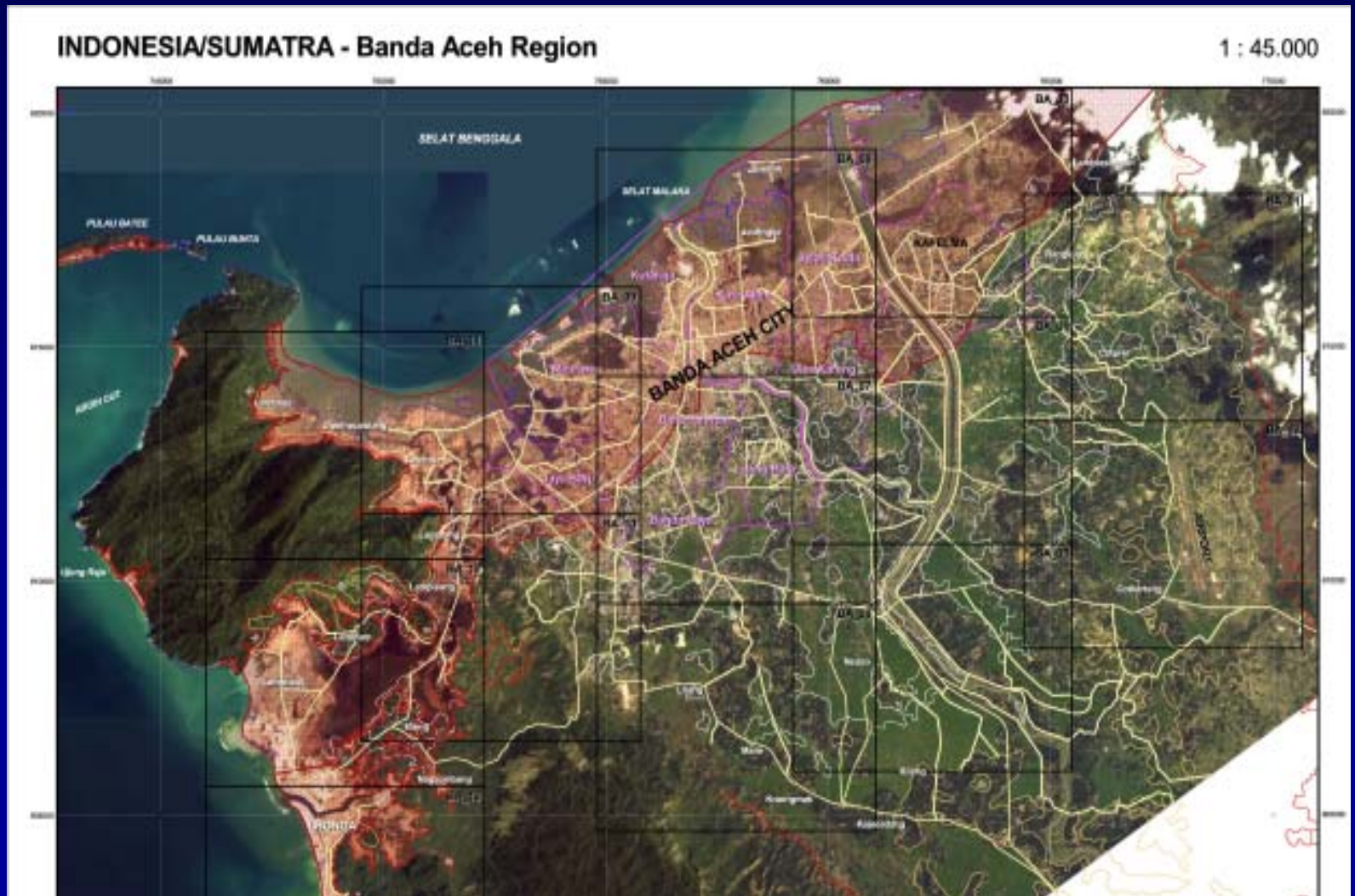
バンダアチェ観測所における 本震記録



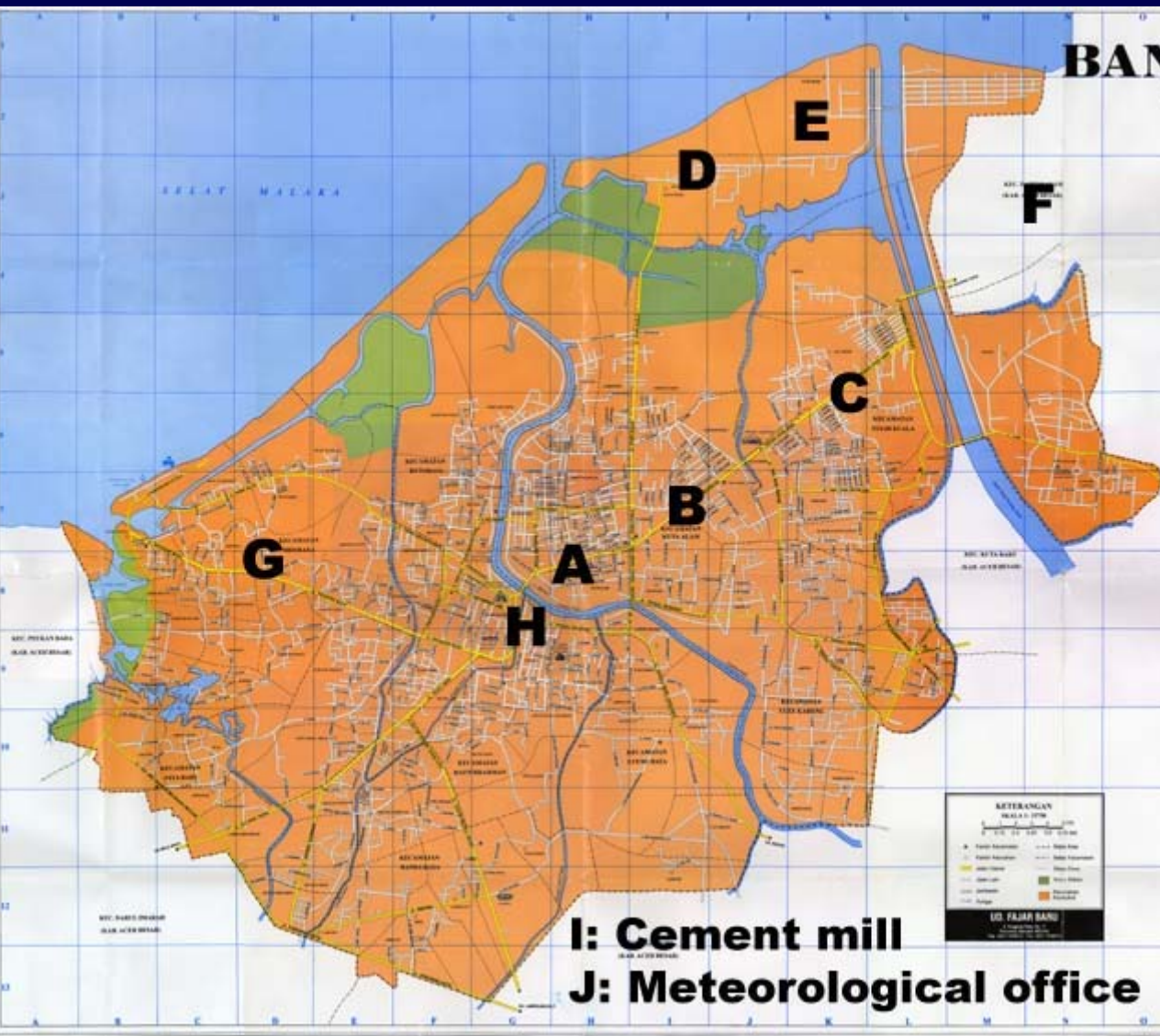
アンケート震度・津波調査

- 被災地域での住人へのアンケートに基づく地震動(気象庁震度)・津波の評価
 - 震度:「アンケートによる地震時の震度の推定」(太田裕ほか、1979)に基づく手法
 - 津波:高さ,回数,地震後到達時間など、独自に作成
 - アンケートの英訳・インドネシア語訳を作成し、Syiah Kuala大学の協力によりアンケートを実施
- 総回答数:震度174、津波64

バンダアチェにおける津波浸水域



Banda Aceh市におけるゾーニング



- 市内で7ヶ所, 他4ヶ所でゾーニング
- A ~ Cはメインストリート沿い(Jl. Mohammad Daud Beureueh)で津波浸水域
- D ~ Gは津波被害甚大地域
- HはGrand Mosque周辺(津波による被害少、地震被害のためのレファレンスポイント)

Banda Acehにおけるアンケート震度

- A: 5.56
- B: 5.48
- C: 5.52
- D: 5.49
- E: 5.51
- F: 5.79
- G: 5.36
- H: 5.60
- I: 4.92

* 値は暫定値



おおむね震度5弱～強程度

Banda Acehにおける津波高さ

- A: 1.5m(1波目), 2.5m(2波目)
- B: 10m(1), 30m(2), 20m(3)
- C: 3m(1), 5m(2)
- D: 7m(1), 10m(2)
- E: 1m(1), 4m(2), 10m(3)
- F: 8m(1), 8m(2)
- G: 20m(1), 30m(2)
- H: 1m(1)
- I: 10m(1), 15m(2)

* 値は回答代表値(暫定)



到達時刻の平均は地震後15～20分

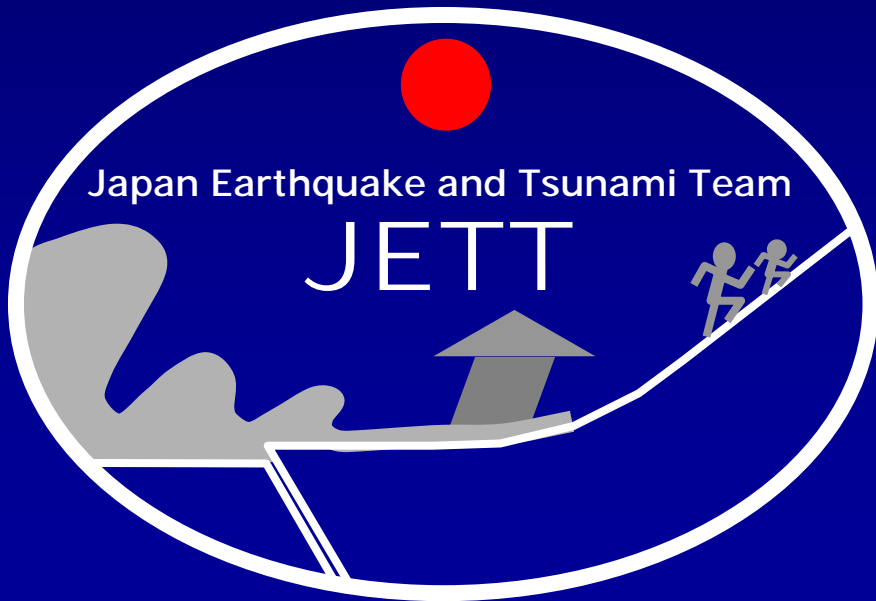
その他津波アンケート結果

- 大地震後津波が来ることを知っていたか？
 - 64名中63名 No(1名無回答)
- 津波に巻き込まれたか？
 - Yes(道路上で(39), 家で(9)), No (16)
- 津波からどのようにして逃げたか？
 - 浮遊物につかまった(14), 家に駆け上った(12), 高所に逃げた(10), 木に登った(6), モスクに逃げた(5)...

今後の作業

- 詳細なデータ整理 (ばらつきの評価など)
- ムラボー、セメント工場等の震度も評価
- 東大・都司先生らによる津波高さ計測結果などとの比較
- 地震動に関する項目 (強さや継続時間) について、アンケート震度等との比較
- 対策に関するコメントの整理

STRUCTURE AND INFRASTRUCTURE SURVEY IN BANDA ACEH



Hirokazu IEMURA

Yoshikazu TAKAHASHI

Mulyo Harris Pradono

Graduate School of Civil Engineering
Kyoto University, Kyoto, Japan



North

ANDAMAN SEA

Ulleelheuo

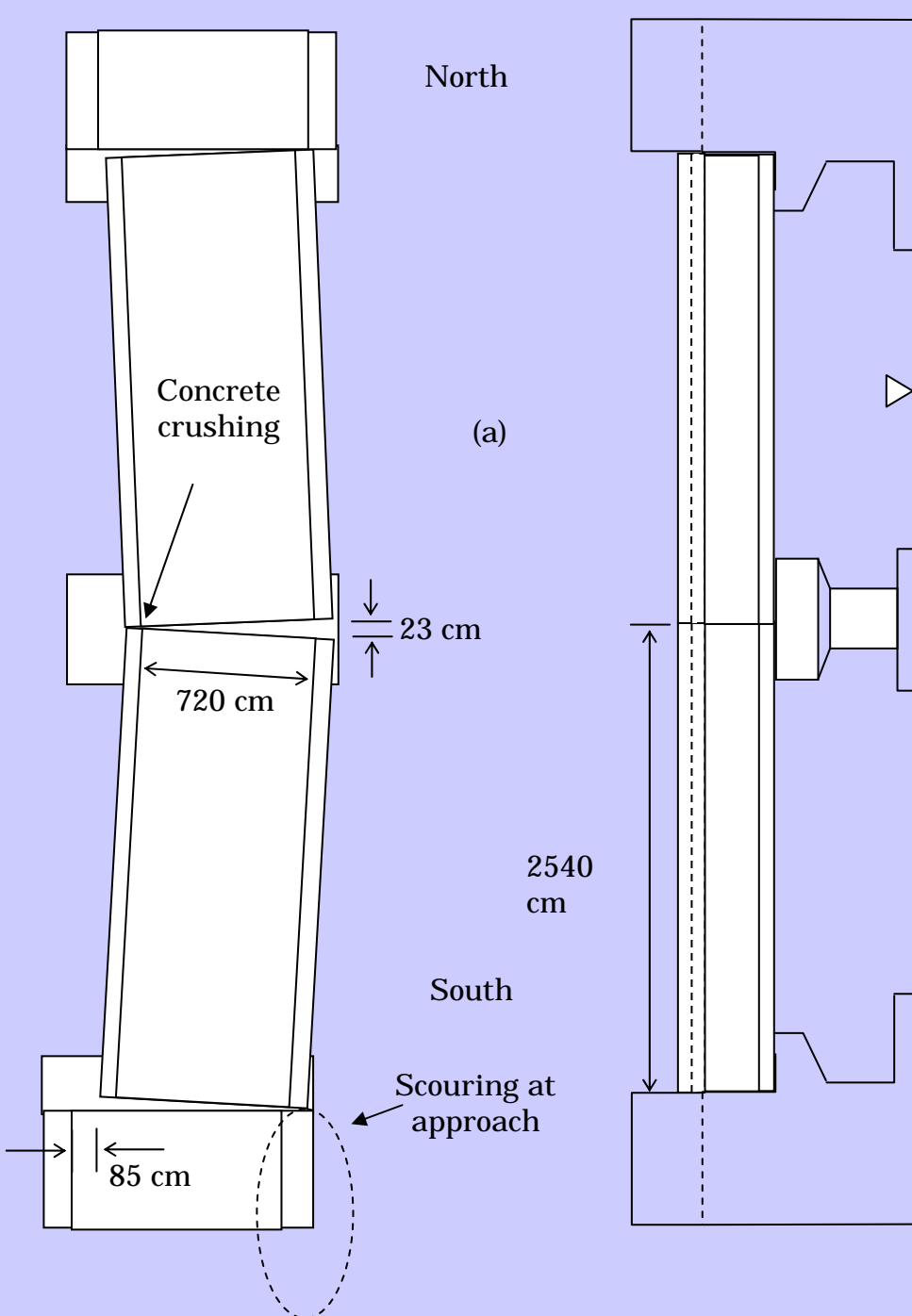
Two of the surveyed bridges, March 2005

No.1 Asoe Nanggroe

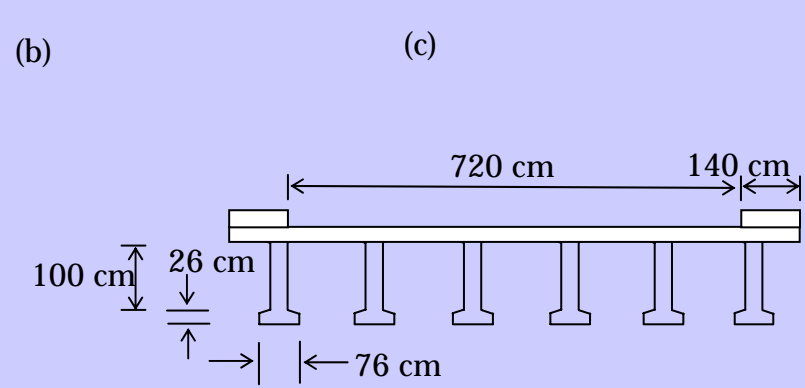
No.20 Peukan Bada

Satellite photo
December 29, 2004

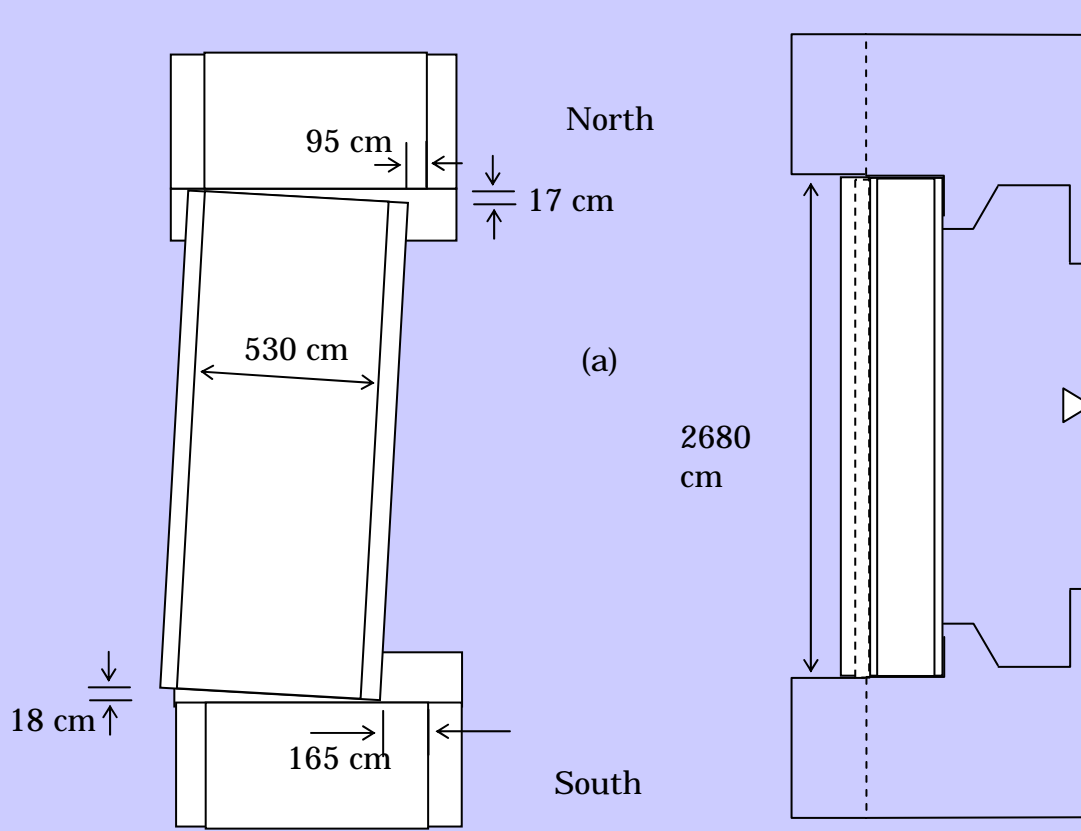
Photo Source: Digital Globe
<http://www.digitalglobe.com>



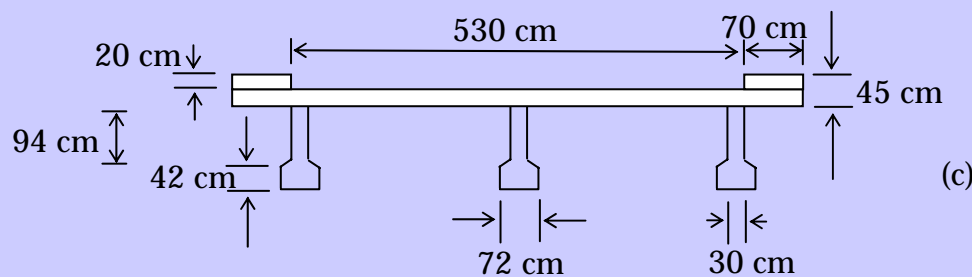
Two span bridge supported by RC girders



Bridge No.1
Asoe Nanggroe
(Dimensions and Displacements)



One span bridge
supported by
RC girders



Bridge No.20
Peukan Bada
(Dimensions and
Displacements)

Estimated water velocity that causes bridge to move

Case Study: No.20
Peukan Bada Bridge

Area of attack, $A = 48.51 \text{ m}^2$

Mass of 3 girders + 1 deck, $m = 227,264 \text{ kg}$

Weight, $W = m \times g = 2,227,187 \text{ Newton}$ $g = 9.8 \text{ m/s}^2$

Resisting force, $F_f = W \times \mu = 668,156 \text{ Newton}$ $\mu = 0.3 \text{ m/s}^2$

Fluid drag force, $F_d = 0.5 \quad C_d v^2 A = F_f$ (bridge start moving)

$$v = \sqrt{\frac{2F_f}{\rho C_d A}} = \sqrt{\frac{2 \times 668,156}{1000 \times 2.0 \times 48.51}} = 3.71 \text{ m/s} \approx 13.4 \text{ km/h}$$

Estimated water velocity that causes bridge to move

Case Study: No.20
Peukan Bada Bridge

Previous calculation did not
consider water uplift force

Considering water uplift force, the velocity is calculated as:

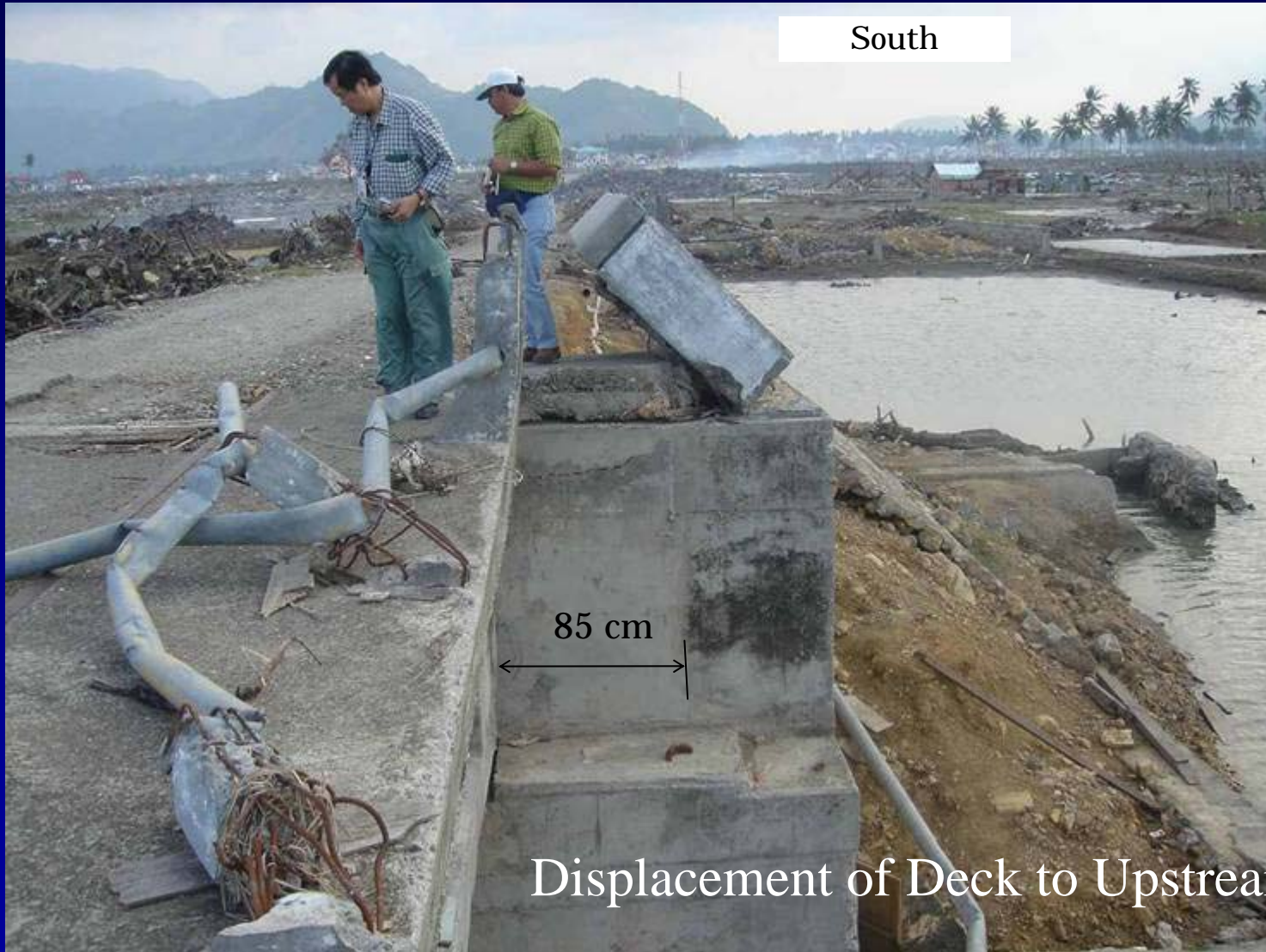
$$v_{wu} = 0.775 \times 13.4 = 10.4 \text{ km/h}$$

Next Research

- To calculate water-dragging velocities for other bridges
- Recommendations for tsunami-prone bridges
- Publications

Bridge No.1 Asoe Nanggroe

March 04, 2005



Bridge No.1 Asoe Nanggroe

March 04, 2005



Upstream



Downstream

(photo from Northern Abutment)

(photo from Southern Abutment)

Displacement of Decks to Upstream Direction

Bridge No.1 Asoe Nanggroe

March 04, 2005



(Gap between decks at the upstream side)

(Crushing of deck concrete at the downstream side)

Bridge No.1 Asoe Nanggroe

March 04, 2005



(Scouring at Southern Approach)



(Scouring at Northern Approach)

Bridge No.20 Peukan Bada

March 04, 2005



One-span Peukan Bada Bridge
(photo facing the north)













Meulaboh from Helicopter

March 03, 2005



Before boarding

Meulaboh from Helicopter March 03, 2005

On board...



Meulaboh from Helicopter March 03, 2005

On the way...



Meulaboh from Helicopter March 03, 2005

On the way...



Meulaboh from Helicopter March 03, 2005



Meulaboh from Helicopter March 03, 2005



Meulaboh from Helicopter March 03, 2005

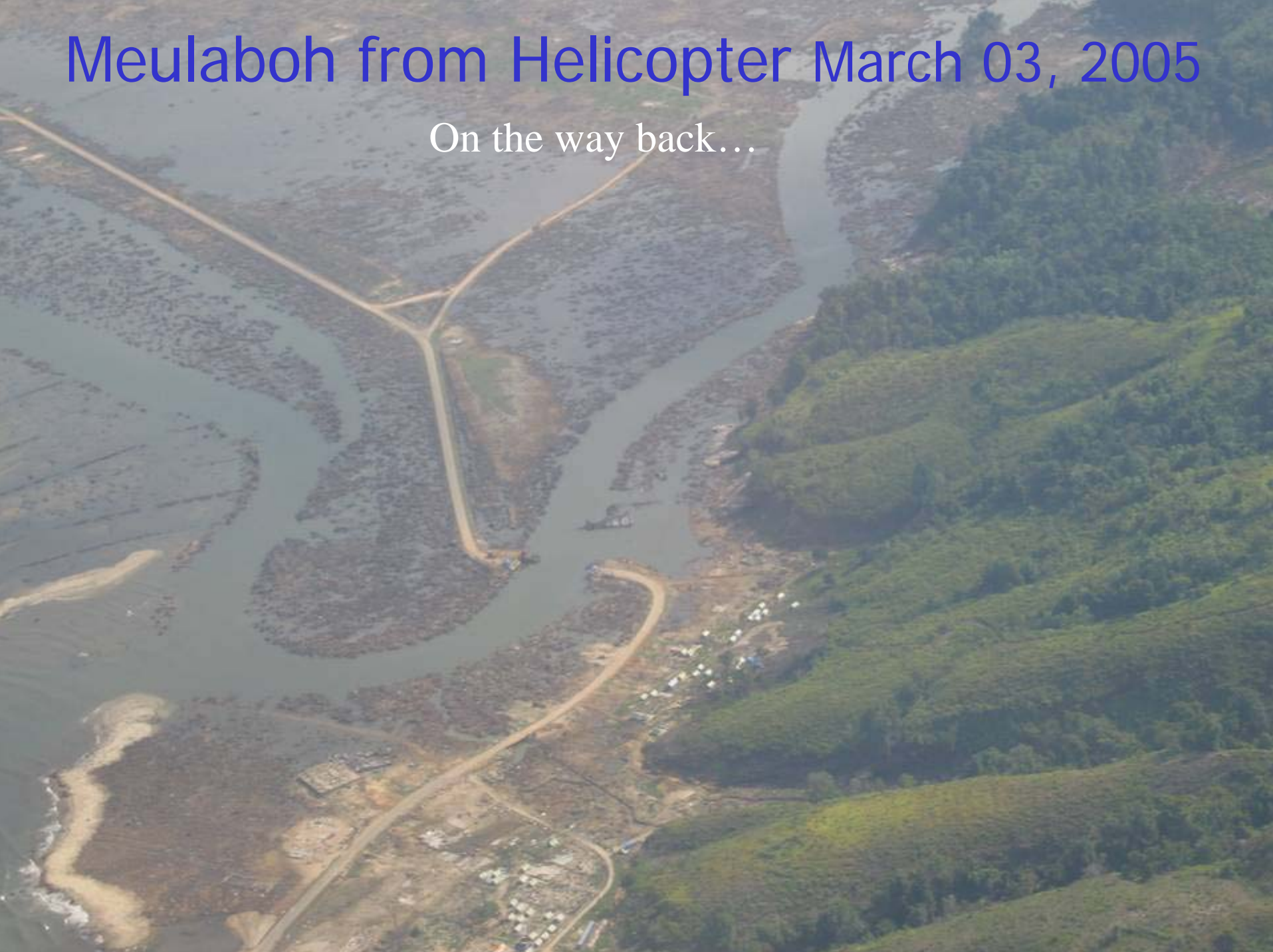


Meulaboh from Helicopter March 03, 2005

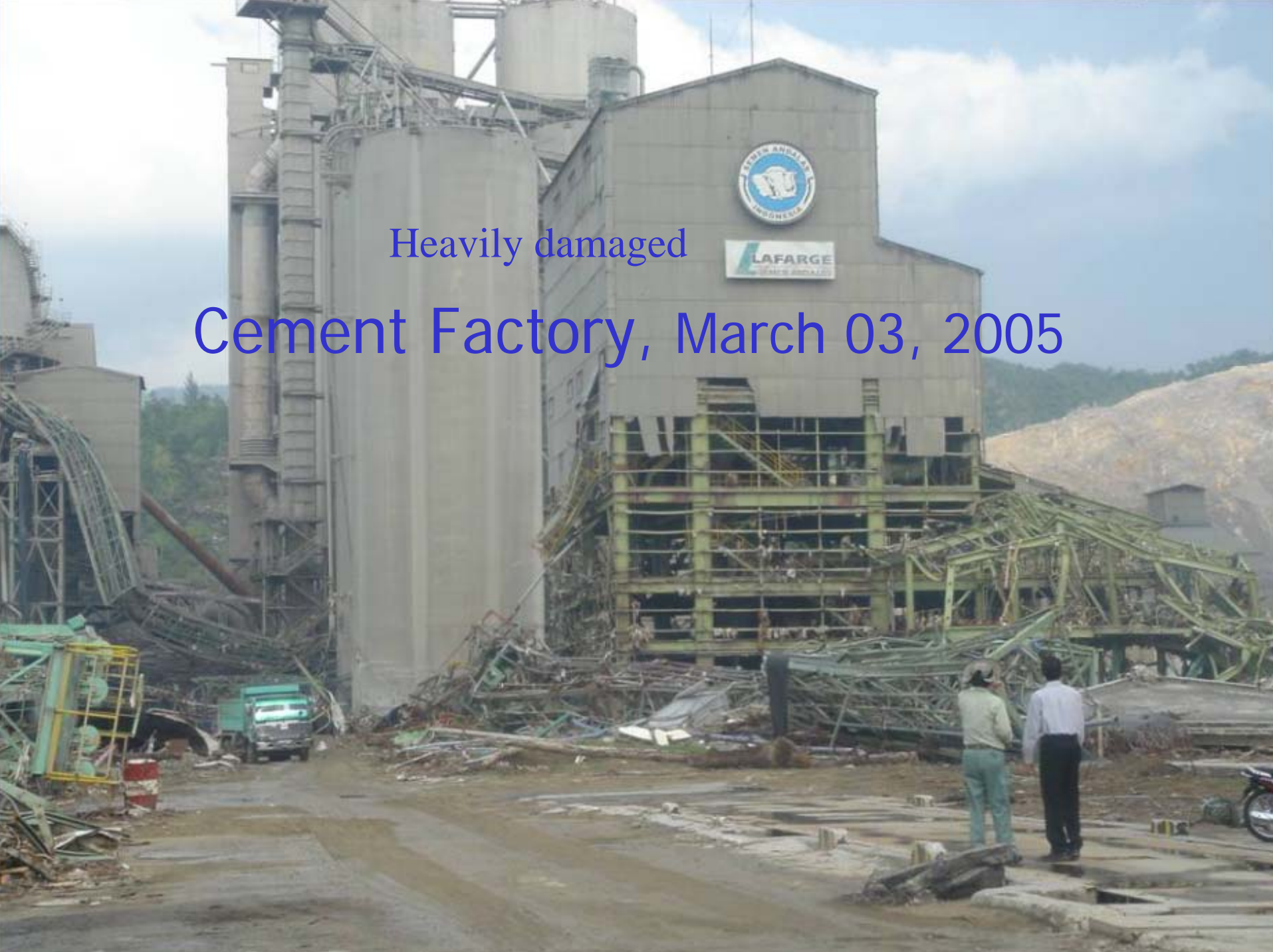


Meulaboh from Helicopter March 03, 2005

On the way back...



Heavily damaged
Cement Factory, March 03, 2005



Cement Factory, Satellites Photos



Photo Source: Digital Globe
<http://www.digitalglobe.com>



Heavily Scoured

Cement Factory, March 03, 2005

Cement Factory, March 03, 2005

Heavily damaged
conveyor belt



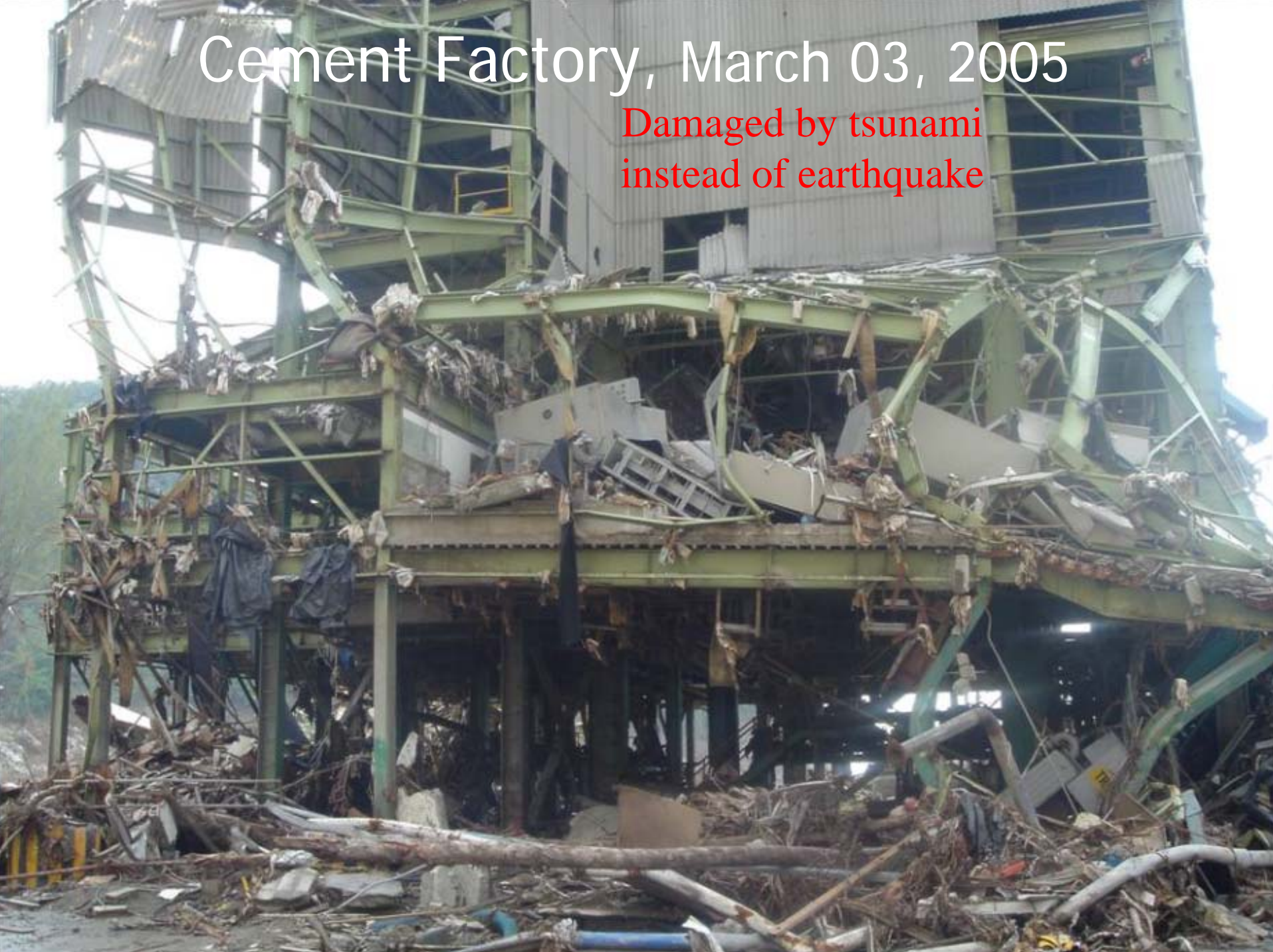
Cement Factory, March 03, 2005

Intact Silos



Cement Factory, March 03, 2005

Damaged by tsunami
instead of earthquake

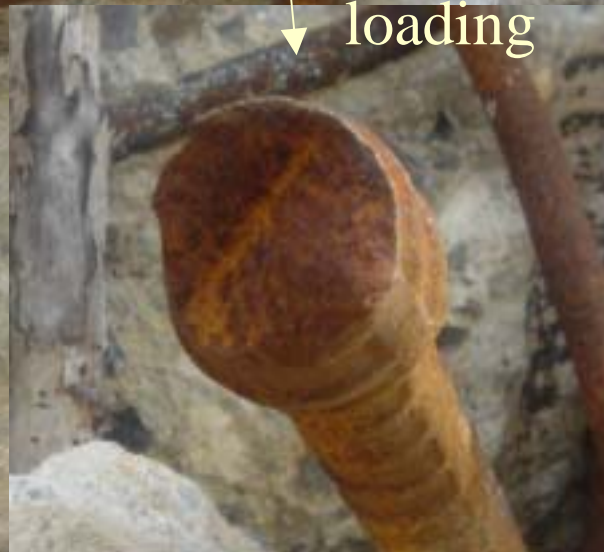


Cement Factory, March 03, 2005

Two different failure mechanisms

Static loading

Cyclic loading



Khao Lak, Thailand, March 09, 2005



Khao Lak, Thailand, March 09, 2005

