

# ***NRC Public Hearing***

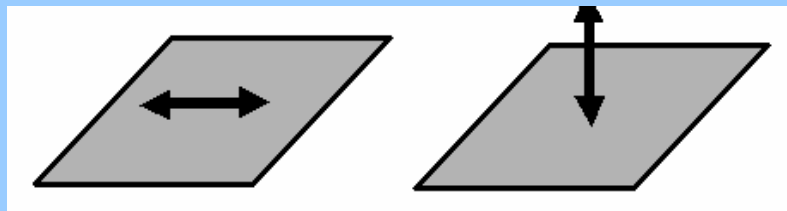
## ***IEEE-344 Shake Table Coherence and Correlation Limits***

*9 December 2008*

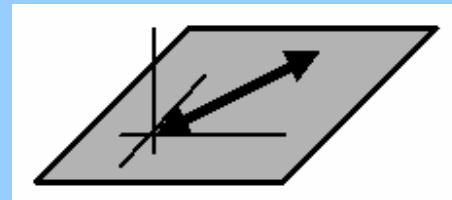
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# SHAKE TABLE COHERENCE AND CORRELATION

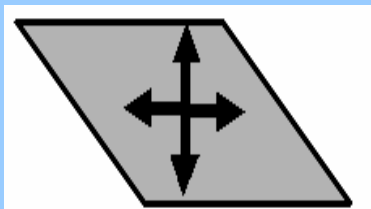
- Shake tables simulate earthquakes in 1, 2, or 3 axes
- Real earthquakes occur in 3 axes and so more table axes is considered to yield a better test
- If a table is “vector biaxial” or not controlled well it is not truly biaxial or triaxial



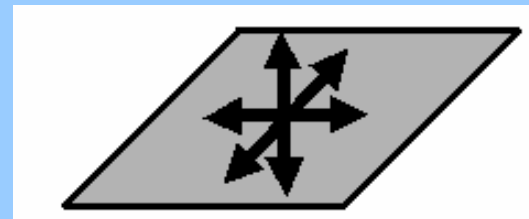
UNIAXIAL



VECTOR BIAxIAL



INDEPENDENT BIAxIAL



INDEPENDENT TRIAXIAL

## **HOW GOOD IS GOOD ENOUGH?**

### **HOW DO WE TELL IF A TABLE IS NOT VECTORIZING OR POORLY CONTROLLED?**

- **Compare each pair of table signals (X/Y, X/Z, Y/Z)**
- **Use COHERENCE = frequency function between 0.0 and 1.0. 0.0 means very independent and 1.0 means essentially identical.**
- **Or use CORRELATION COEFFICIENT = function of time delays (or time shifts) through the strong motion are between -1.0 and +1.0. 0.0 means not very similar. Closer to +/- 1.0 means more similar.**

# **HOW DO WE DECIDE ON REASONABLE LIMITS ON COHERENCE / CORRELATION COEFFICIENT FUNCTIONS?**

- **25 YEARS AGO KANA STUDIED SEVERAL REAL EARTHQUAKE GROUND MOTIONS AND FOUND ACTUAL AVERAGE VALUES OF COHERENCE ABOUT 0.5 AND VARIOUS ADDITIONAL STUDIES SUGGESTED ABS(CORRELATION) ABOUT 0.3.**
- **THESE VALUES HAVE BEEN IN IEEE-344 AND USED AS CRITERIA IN THOUSANDS OF SEISMIC TESTS. NO FAILURES HAVE BEEN ASSOCIATED WITH THIS PRACTICE.**
- **A NEW UNPUBLISHED EARTHQUAKE DATA REVIEW MAY SUGGEST THAT THESE NUMBERS SHOULD BE RECONSIDERED, ESPECIALLY FOR VERTICAL MOTION.**
- **THE INDUSTRY POSITION IS THAT THERE ARE NO KNOWN SAFETY IMPROVEMENTS ASSOCIATED WITH THE REDUCTION AND NO ADEQUATE JUSTIFICATION PROVIDED FOR THE PROPOSED REDUCTION. ALSO THERE ARE TECHNICAL ISSUES AS DISCUSSED BELOW.**

# **REASON 1 TO KEEP CURRENT LIMITS: REALISM AND PRACTICALITY**

- **THE CURRENT COHERENCE / CORRELATION LIMITS ARE BASED ON ACTUAL EARTHQUAKE GROUND MOTIONS. ASKING FOR LOWER LIMITS MAY MAKE THE SIGNALS “LESS EARTHQUAKE LIKE.”**
- **ANY NEW DATA NEEDS WIDE REVIEW AND MAY OR MAY NOT SUGGEST A CHANGE TO VERTICAL MOTION LIMITS.**
- **THERE IS NO STUDY OR DATA SHOWING THAT LOWER COHERENCE / CORRELATION LIMITS WILL INCREASE SAFETY OR SAFETY MARGINS.**
- **PAST TETS AND SHAKE RABLES**

## **REASON 2: COUPLED IN STRUCTURE SPECTRA**

- **MOST EQUIPMENT SEISMIC TESTS ARE PERFORMED ACCORDING TO HIGHLY PROCESSED AND MODIFIED RESPONSE SPECTRA ASSOCIATED WITH THE STRUCTURE RATHER THAN ON THE GROUND.**
- **THESE IN-STRUCTURE SPECTRA ARE MORE HIGHLY CORRELATED DUE TO THE MULTI-AXIS MODES OF VIBRATION OF A STRUCTURE (HORIZONTALLY MORE THAN VERTICALLY).**
- **HENCE IT IS DIFFICULT AND OFTEN MATHEMATICALLY IMPOSSIBLE TO CREATE DEVICES HISTORIES THAT REDUCE COHERENCE / CORRELATION FURTHER. THIS IS NOT DUE TO TABLE LIMITATIONS.**

## **REASON 3: ROTATED AXES CORRELATION**

- **WELL CONTROLLED SHAKE TABLES CAN REPRODUCE LOWER COHERENCE / CORRELATION SIGNALS IF THEY ARE MATHEMATICALLY POSSIBLE.**
- **IF LOW COHERENCE / CORRELATION SIGNALS ARE PRODUCED ON A TABLE AND THE TEST ITEM IS ROTATED ON THE TABLE THE TIME HISTORIES IN THE NEW COORDINATE SYSTEM OFTEN WILL BE MORE CORRELATED.**
- **ONE MUST THUS CONSIDER THE FACT THAT EQUIPMENT CAN BE MOUNTED IN ALL ORIENTATIONS AND THEREFORE WILL SEE A CORRELATED SIGNALS IN ANY CASE.**

## **RECOMMENDATION**

- **MAKE NO CHANGES IN THE CURRENT VALUES UNLESS MORE JUSTIFICATION IS PROVIDED THAT A REDUCTION IN THESE VALUES WOULD IN FACT CONTRIBUTE TO INCREASED PUBLIC SAFETY. THERE IS AMPLE INDUSTRY EVIDENCE TO SHOW THAT PUBLIC SAFETY IS NOT COMPROMISED USING THE CURRENT VALUES.**