TELEDYNE
ENGINEERING SERVICES

TRIP REPORT NO. 2202

VISIT TO
IMPELL CORPORATION
WALNUT CREEK, CA

January 22, 1986

PURPOSE: Meeting on Slenderness Ratio Limit and Audit of Impell Procedures

TES Personnel: R.D. Ciatto, E.A. Solla

This meeting was in three parts:

- o Impell discussed the issue of slenderness ratio limit imposed by the AISC specification and its applicability to CPSES cable tray hangers.
- o TUGCO gave a brief status report on the cable tray verification program.
- o The NRC and its consultants commented on Impell design criteria and procedures.

Present at this meeting were representatives of TUGCO, Impell, EBASCO, Robert L. Cloud and Associates (RLCA) and Jack Benjamen Associates (JBA) which is part of the third party review team. Mr. David Jeng of the NRC attended along with his consultants from Brookhaven, Engineering Analysis Services and Teledyne. A complete attendance list is given in Attachment 1.

Mr. Randy Wheaton of Impell presented the TUGCO position on AISC slenderness ratio limits and their applicability to CPSES cable tray hangers. His slides are given in Attachment 2. In summary*, TUGCO and its consultants, RLCA, Impell, and EBASCO believe that the AISC slenderness ratio limit of 200 for compression members does not apply to CPSES cable tray hangers. They reason that compressive loads in these members are small, they are short duration loads and the members are subject to tension rather than compression most of the time. Also, they correctly point out that the code formula (Euler equation) for long columns is valid for unlimited slenderness ratios. Furthermore, they are correct in stating that column test data gives better agreement with long slender columns, which buckle elastically, than with short and intermediate columns, which buckle inelastically.

* Mr. Wheaton gave this presentation on November 26, 1985. It is fully summarized in TES Trip Report No. 2185.

TUGCO is taking the position of using the code factor-of-safety of 1.92 for all members subjected to axial compression which have slenderness ratios in excess of 126 (applicable to A36 steel). TUGCO and its consultants will adhere to slenderness ratio (kL/r) limits for members supported by the floor below the cable tray system. These members are in compression due to dead weight and hence, they are defined as columns rather than hangers which are subjected to occasional compressve forces.

Mr. Eidinger of Impell stated that the hangers are subjected to very small compressive stresses, from 100 to 200 psi, due to seismic loadings. Some of the slenderness ratios are between 300 and 400 and Mr. Alexandru stated that 14% (about 500 supports) in Unit 2 are being modified to reduce kl/r to less than 200 by adding longitudinal braces to transverse supports so that the lower ends of the supports are not "free". Such modifications would be extremely difficult in Unit 1.

The NRC consultants did not agree with Mr. Wheaton on one issue. Impell feels that there is a connection between impact type loads, such as pile driver loads and crane wheel impact loads, and seismic loads. They stated that seismic loads are shorter duration than wheel loads; this is a point which the NRC consultants disputed and which Impell did not quantify. They stated that their reason for bringing this up is that AISC allows impact load to be disregarded for column evaluation. However, the cable tray hangers are subjected to seismic loads, not impact loads, and the AISC specification requires evaluation of seismic compression stresses in columns. The staff consultants' position is that cable tray hangers must be evaluated for compressive stress resulting from seismic loads.

At the conclusion of Impell's presentation on slenderness ratio limits, Mr. Svensson of RLCA presented his position on the subject. This was basically an endorsement of the Impell positon. His notes are given in Attachment 3. On a point of interest, Edgar Hee of RLCA stated that he would try to obtain additional test data for long slender columns.

There is one final point to note on the slenderness ratio issue. Some CPSES cable tray hangers exceed the AISC recommended slenderness ratio limits for tension members. Since these are non-mandatory requirements and since they are not intended to address structural integrity it is our opinion that this is acceptable as long as code factors-of-safety are met.

Mr. Harrison of TUGCO gave a brief presentation on the current status of the cable tray verification program. The site is currently under a stop-work order issued in response to a previous NRC site audit. The procedure for red-lining drawings was revised on January 10 and there was a trial walkdown using this procedure on January 15. Twenty-five to thirty walkdown teams will restart around February 1.

Impell is just getting started on Unit 1. No verification is complete at this time since they have not received red-line drawings. EBASCO has verified 42 supports and they have 800 supports in progress.

Mr. Jeng of the NRC requested that TUGCO provide him with the basis for using AISI criteria. He also asked why RLCA should not evaluate adequacy of Gibbs and Hill cable tray design since support spacing requirements were established by Gibbs and Hill.

The meeting concluded with comments by the NRC and its consultants on Impell documents. Important comments are summarized below.

Impell Interface Control Instructions

Appendix A. Fig. 1 - It is not apparent how the field interacts with engineering for design changes.

Response. Impell presented a revised figure showing design change control. (This should be considered for further review.)

Impell Design Criteria and Methodology

P. 3-2. There are no requirements given for bolted steel connections even though specific requirements are given for welded connections.

Impell Instruction PI-01, Simplified Analysis Methods

p. 6. Thermolag has a considerable weight and it is properly taken into account in the analysis. What is the justification for ignoring thermolag in the dynamic system tests?

p. 6 Section 3.3d. Support reactions on embedded plates must be evaluated just as expansion anchor loads are evaluated. Where are the allowable embedded plate loads?

General Comment

There are some sections of the project instructions where ambiguous wording allows analysts to control the workscope. These sections were pointed out to TUGCO and its consultants. They should be revised so that the intended workscope is not reduced by the analysts.

Observations/Recommendations

The use of cable tray support hangers with slenderness ratios in excess of 200, the limit for compression members, is technically acceptable providng that compressive stresses are within code limits. If stress limits are met, the use of long slender members does not reduce the design margin of the support. However,it is observed that TUGCO's comparison of wheel impact loads and pile driver loads to seismic loadings as one of the reasons for exceeding AISC kl/r limits is not applicable.

Other items to be considered in future audits should include the following:

- Both static and dynamic analyses, including generation of loads, performed by EBASCO and Impell should be audited.
- Compressive stress calculations for hangers should be reviewed. Impell stated that seismic compressive stresses are only about 100 to 200 psi.
- Unit 2 modifications to transverse supports include the addition of longitudinal brace members. The calculations should be reviewed to determine if the weight of these braces has been included in the analysis.
- Calculations should be reviewed to ensure that support reactions on embedded plates are properly reconciled with allowable loads.
- The interaction between Gibbs and Hill and other TUGCO consultants should be reviewed to determine if interfaces are clearly documented and to determine the adequacy of the methods of qualification of the cable trays themselves for loads determined by Impell and EBASCO.

- With respect to design change control, the interaction between field and engineering (EBASCO/Impell) should be examined to determine if field changes are factored into analyses per ANSI N45.2.11.

- Sampling of calculations audited by RLCA per the CPRT program plan, Appendix D, should be audited.

Raymond D. Ciatto

Eric A. Solla

RDC/EAS/mam

cc: D.F. Landers
J.Q. Cagin
Project 6410 Trip File

Attachment I

Meeting at Impell Corp.,
Walnut Creek

Comanche Peak - Cable Tray Support Verification

NAME	ORGANIZATION	PHONE #
Robert Philbrick	Impell Corp.	415-943-4500
Brian Ramsey	Impell Corp	415-943-4500
Rene Alexandru	EBASCO, Inc.	
Edgar Hee	RLCA	415-841-9296
Tony Chen	Impell	415-943-4500
Per Svensson	RLCA	415-841-9296
Jerry Kralik	Impell	415-943-4500
Shiraz Jaffer	Impell	415-943-4500
John Eidinger	Impell	415-943-4500
Randy Wheaton	Impell	415-943-4500
Paul Bezler	BNL/NRC	516-282-2447
R.D. Ciatto	TES/NRC	617-895-3350
Victor Ferrarini	EAS/NRC	401-884-5228
Eric Solla	TES/NRC	617-890-3350
David Jeng	NRC	301-443-7974
H.A. Harrison	TUGCO	817-897-8691
John W. Reed	JBA	415-969-8212
Charles Kircher	JBA	415-969-8212

Attachment 2

SLENDERNESS RATIO LIMITATIONS FOR HANGER-TYPE SUPPORTS

PRESENTED TO:

U.S. NUCLEAR REGULATORY COMMISSION

PRESENTED BY:

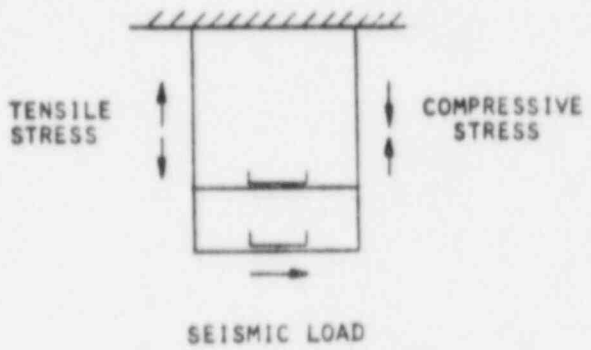
TEXAS UTILITIES GENERATING COMPANY

JANUARY 22, 1986

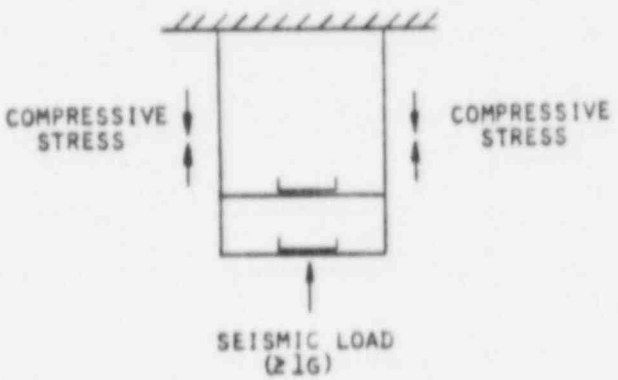
BASIC ISSUE

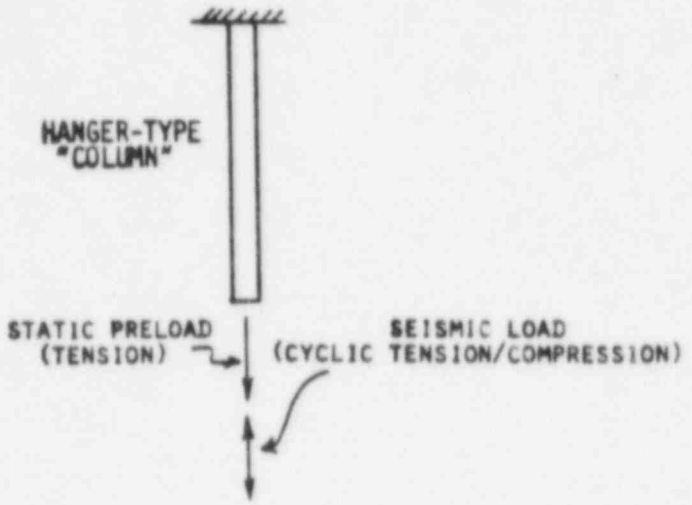
SHOULD AISC CODE LIMITATIONS ON KL/R VALUES BE APPLIED TO HANGER-TYPE RACEWAY SUPPORTS?

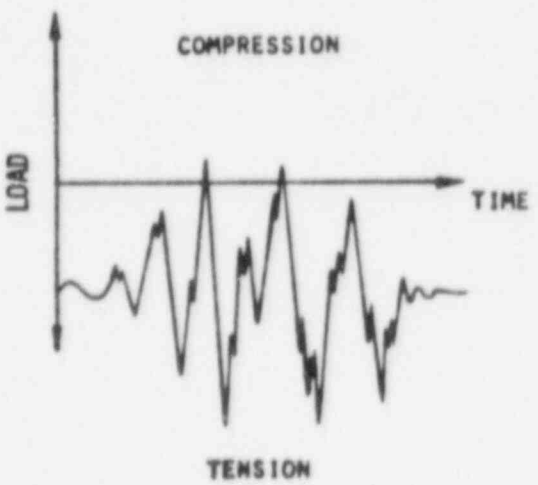
CASE 1:



CASE 2:







AXIAL LOAD IN HANGER-TYPE SUPPORTS

MAJOR CONSIDERATIONS

1. LICENSING COMMITMENTS

2. AISC CODE COMPLIANCE

3. ENGINEERING EVALUATION

1. LICENSING COMMITMENTS

- FSAR SECTIONS 3.7B AND 3.10B:
  - QUALIFICATION BY TEST OR ANALYSIS
  - DEMONSTRATE STRUCTURAL AND FUNCTIONAL INTEGRITY
- FSAR APPENDIX 17: AISC CODE DEFINES ACCEPTANCE CRITERIA FOR ANALYTICAL QUALIFICATION
- APPLICABILITY OF ANY GIVEN CRITERION DEPENDENT UPON SITUATION AT HAND

CONCLUSIONS:

- LICENSING COMMITMENT IS TO APPLY CODES AND STANDARDS IN A RATIONAL MANNER TO ALL ELECTRICAL SYSTEMS AND SUPPORTS

2. AISC CODE COMPLIANCE

- o AISC SPECIFIES KL/R $\leq$ 200 FOR COMPRESSION MEMBERS
- o TUGCO DOES NOT CHALLENGE LIMITATION - ONLY ISSUE IS WHEN TO APPLY IT
- o APPLICABILITY CAN BE EVALUATED BY CONSIDERING THREE MAIN FACTORS
  - BACKGROUND OF KL/R LIMITS
  - TENSION OR COMPRESSION MEMBER
  - STATIC OR DYNAMIC LOAD

2. AISC CODE COMPLIANCE (CONT.)

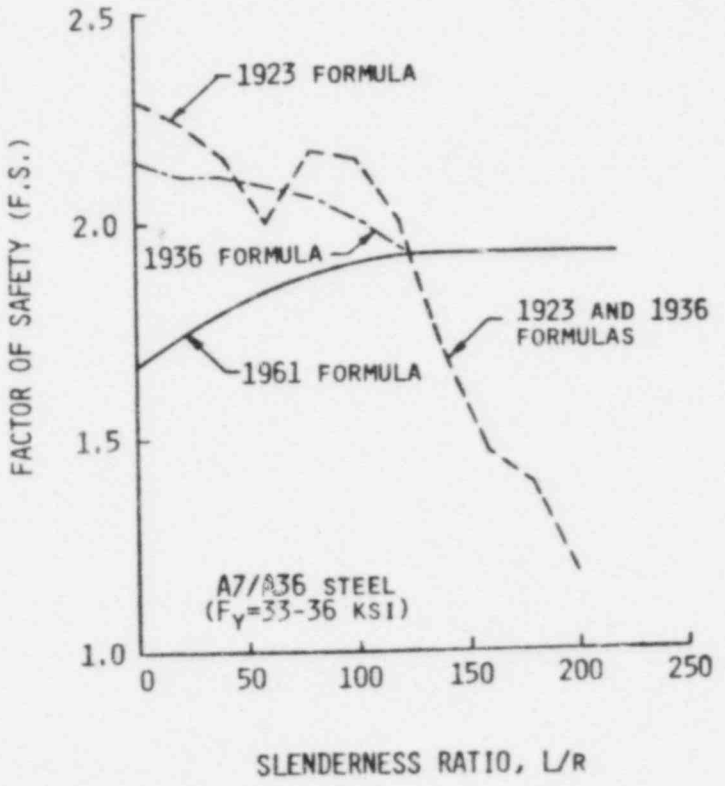
BACKGROUND

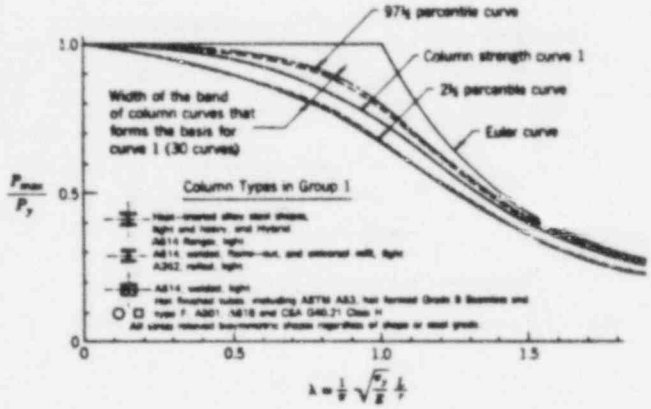
- KL/R LIMIT OF 200 UNCHANGED SINCE EARLIEST EDITIONS
- LIMIT APPEARS TO HAVE BEEN BASED ON DECREASING FACTOR OF SAFETY IN BUCKLING EQUATION FOR HIGH KL/R RATIOS
- SAFETY FACTOR NOW HELD AT 1.92 FOR ALL KL/R GREATER THAN 126
- CURRENT BUCKLING EQUATIONS MORE ACCURATE FOR HIGH KL/R THAN FOR LOW - EXTENSIVE EXPERIMENTAL VERIFICATION
- LIMIT OF 200 NOW APPEARS TO BE ARBITRARY - OTHER CODES VARY LIMIT FROM 180 TO 260 - COLUMN RESEARCH COUNCIL DOES NOT RECOMMEND ANY KL/R LIMITS
- WORLDWIDE, ALL CODES DISCUSS KL/R ONLY IN RELATION TO "TRUE COLUMNS"
  - STATIC COMPRESSION AND BENDING LOADS
  - ALL PRIMARY LOADS
  - NO LOAD REDISTRIBUTION
  - UNSTABLE BUCKLING FAILURES
- HANGER-TYPE SUPPORTS DO NOT MEET ANY OF THE CRITERIA FOR A TRUE COLUMN

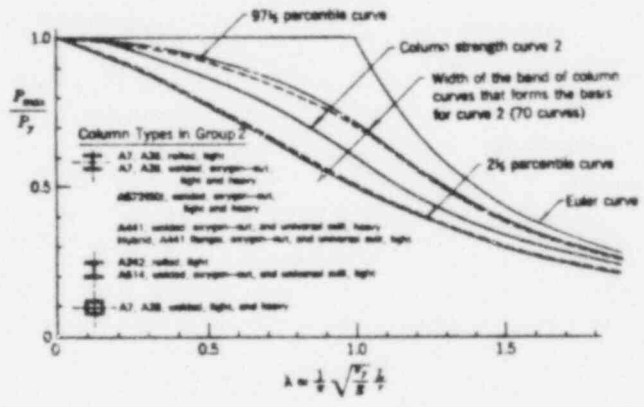
CONCLUSION:

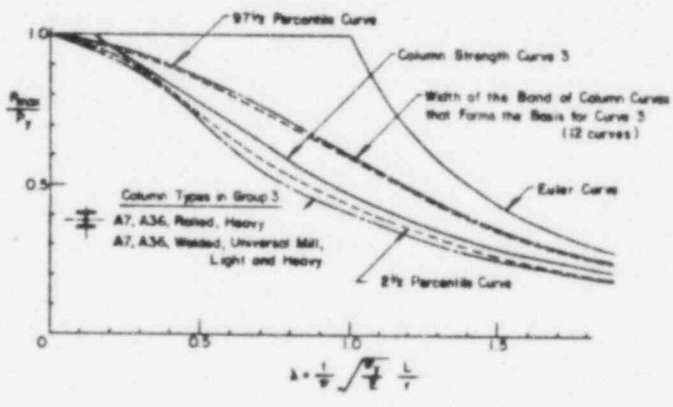
MAXIMUM KL/R VALUE IS ARBITRARY - SOME LIMIT MAY BE ADVISABLE FOR TRUE COLUMNS BUT RELEVANCE TO HANGER-TYPE COMPONENTS IS QUESTIONABLE

FACTORS OF SAFETY IN AISC BUCKLING EQUATIONS

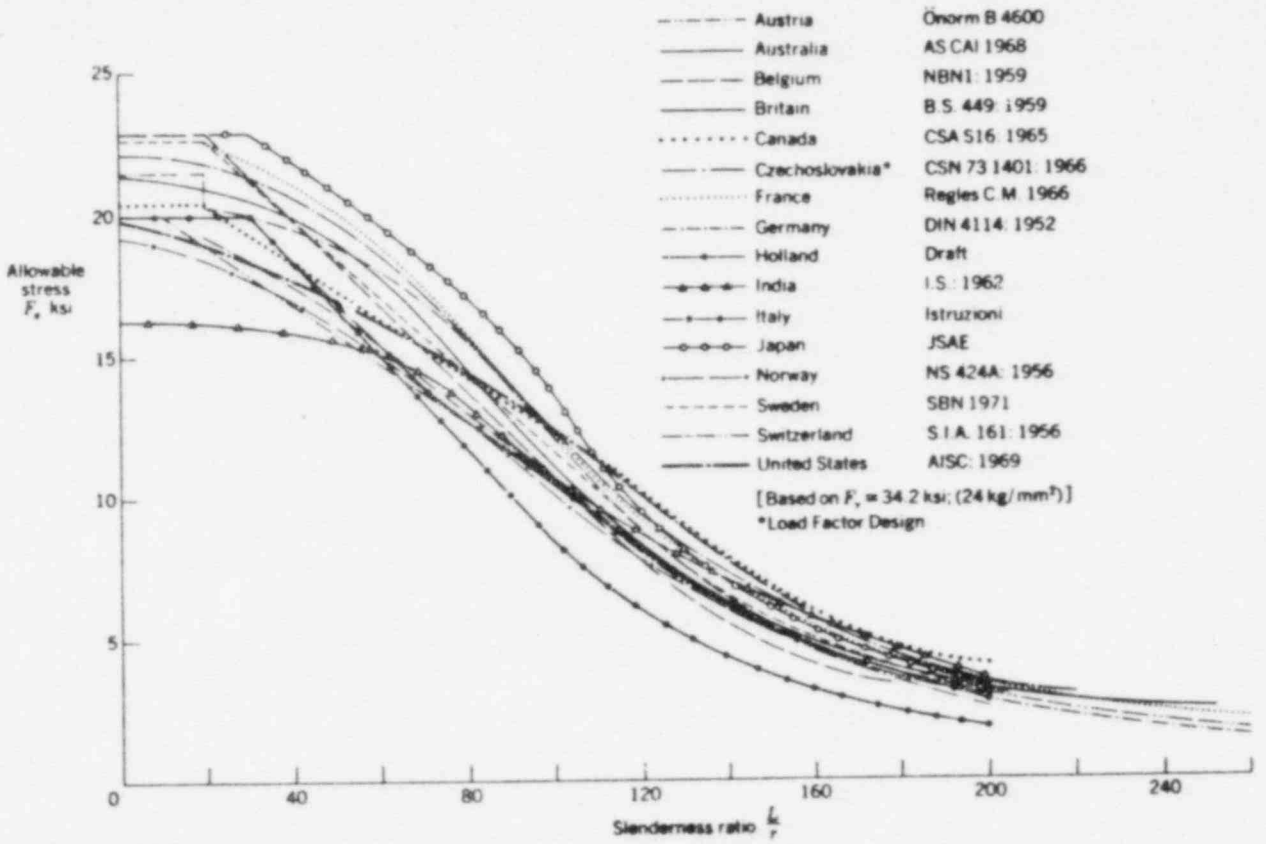








CRC RECOMMENDED COLUMN STRENGTH CURVES



TYPICAL COLUMN STRENGTH CURVES WORLDWIDE

2. AISC CODE COMPLIANCE (CONT.)

TENSION vs. COMPRESSION MEMBERS

- AISC CODE PROVIDES NO DEFINITIONS - INTERPRETATION REQUIRED
- CODE DISCUSSES KL/R ISSUE FOR BOTH TENSION AND COMPRESSION MEMBERS - NOT ALL MEMBERS FALL INTO COMPRESSION CATEGORY
- ANY MEMBER CAN SEE AN INCIDENTAL DYNAMIC COMPRESSION DURING AN EARTHQUAKE
- ONLY CODE REFERENCE TO DYNAMIC LOADS ALLOWS THEM TO BE NEGLECTED IN COLUMN BUCKLING PROBLEMS
- DYNAMIC COMPRESSION ALONE MUST NOT BE A SUFFICIENT BASIS FOR CLASSIFICATION
- ENGINEERING EVALUATION MUST BE PERFORMED TO ASSESS STRUCTURAL FUNCTION, NATURE OF LOADS AND CONSEQUENCES OF POSSIBLE OVERLOADS

CONCLUSIONS:

- NO RIGOROUS OR GENERALIZED CLASSIFICATION POSSIBLE
- CODE TREATMENT OF DYNAMIC COLUMN LOADS SUGGESTS THAT HANGER-TYPE SUPPORTS WOULD FALL INTO TENSION MEMBER CATEGORY

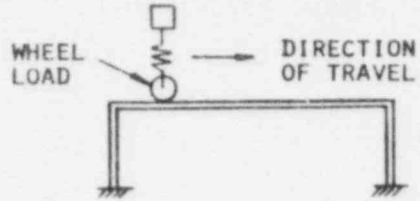
2. AISC CODE COMPLIANCE (CONT.)

STATIC vs. DYNAMIC LOADS

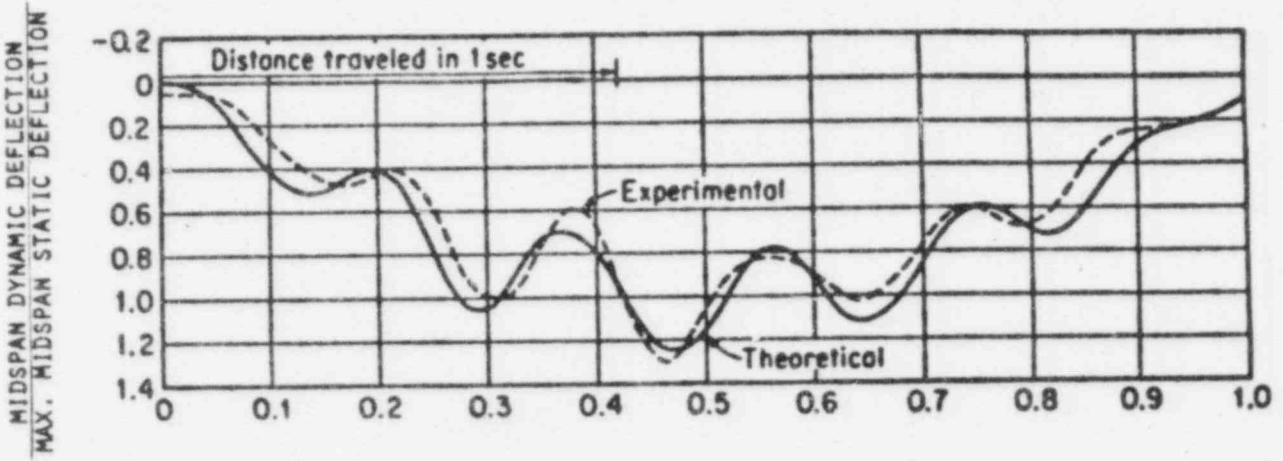
- o AISC CODE SPECIFICALLY ALLOWS "IMPACT" LOADS TO BE DISREGARDED IN COLUMN BUCKLING PROBLEMS
  - "IMPACT" LOAD IS DYNAMIC PORTION OF TRAVELING WHEEL LOAD
  - DURATION OF DYNAMIC LOAD TOO SHORT FOR COLUMN BUCKLING TO OCCUR
- o DYNAMIC LOAD EFFECTS IN TUGCO HANGER-TYPE SUPPORTS ARE LESS SIGNIFICANT IN EVERY RESPECT THAN "IMPACT" LOADS
  - SEISMIC LOADS ARE OF SHORTER DURATION THAN WHEEL LOADS
  - SEISMIC LOAD IS DYNAMIC COMPRESSION SUPERIMPOSED ON STATIC TENSION
  - MAXIMUM COMPRESSIVE LOAD IS FAR LESS THAN P_{CR}
  - DYNAMIC INSTABILITY IS NOT A CREDIBLE PHENOMENON
  - TRUE BUCKLING IS NOT A CREDIBLE PHENOMENON

CONCLUSION:

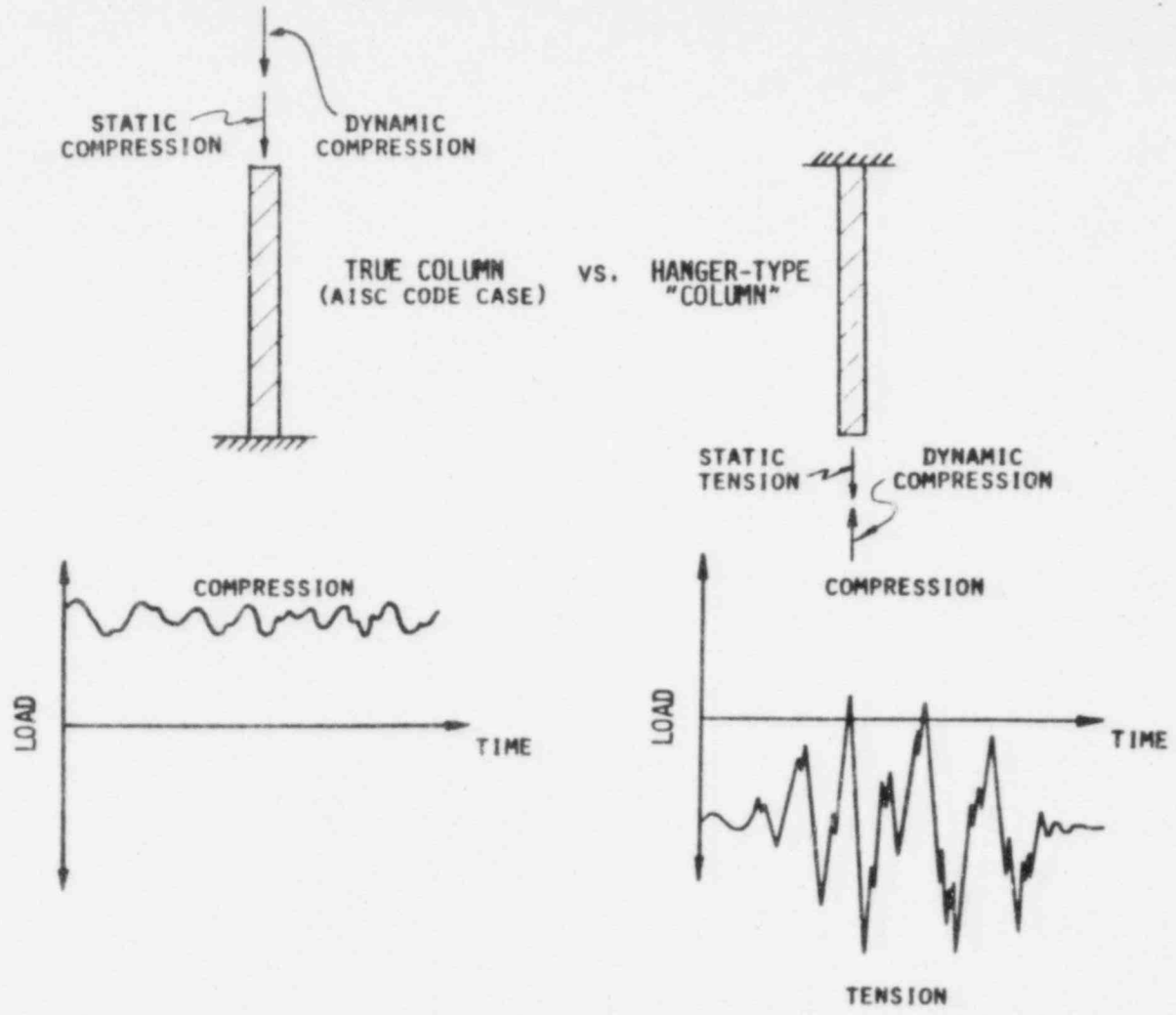
WITHIN THE CONTEXT OF THE AISC CODE, SHORT DURATION COMPRESSIVE LOADS ARE NEGLIGIBLE WITH REGARD TO "COLUMN ACTION" IN HANGER-TYPE SUPPORTS - ONLY STATIC TENSION LOADS REMAIN - KL/R LIMITS NEED NOT BE APPLIED



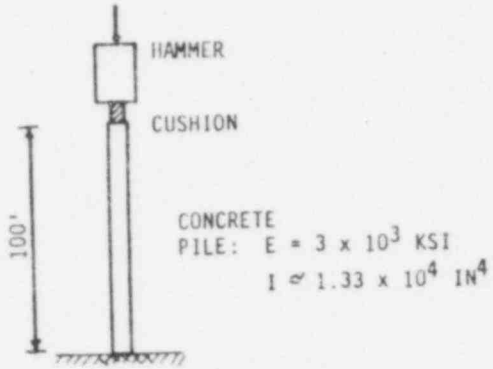
REFERENCE: BIGGS, J.M., INTRODUCTION TO STRUCTURAL DYNAMICS

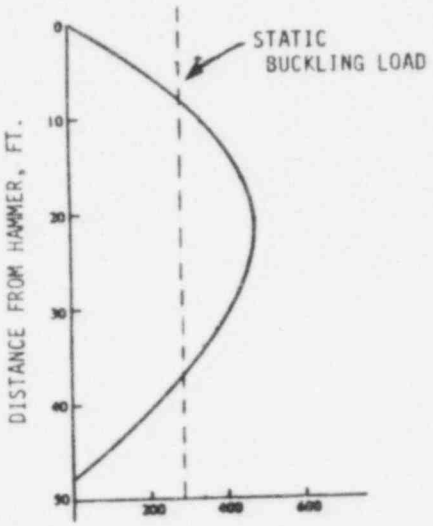


TYPICAL DYNAMIC EFFECTS DUE TO "IMPACT" LOADS



AISC "IMPACT" COMPRESSION vs. CPSES SEISMIC COMPRESSION





$P_e = \frac{\pi^2 EI}{L^2} = 273.5$ KIPS

$\frac{KL}{R} \simeq 210$

REFERENCE: CLOUGH & PENZIEN,
DYNAMICS OF STRUCTURES

DYNAMIC PILE-DRIVING COMPRESSION FORCES

DYNAMIC INSTABILITY

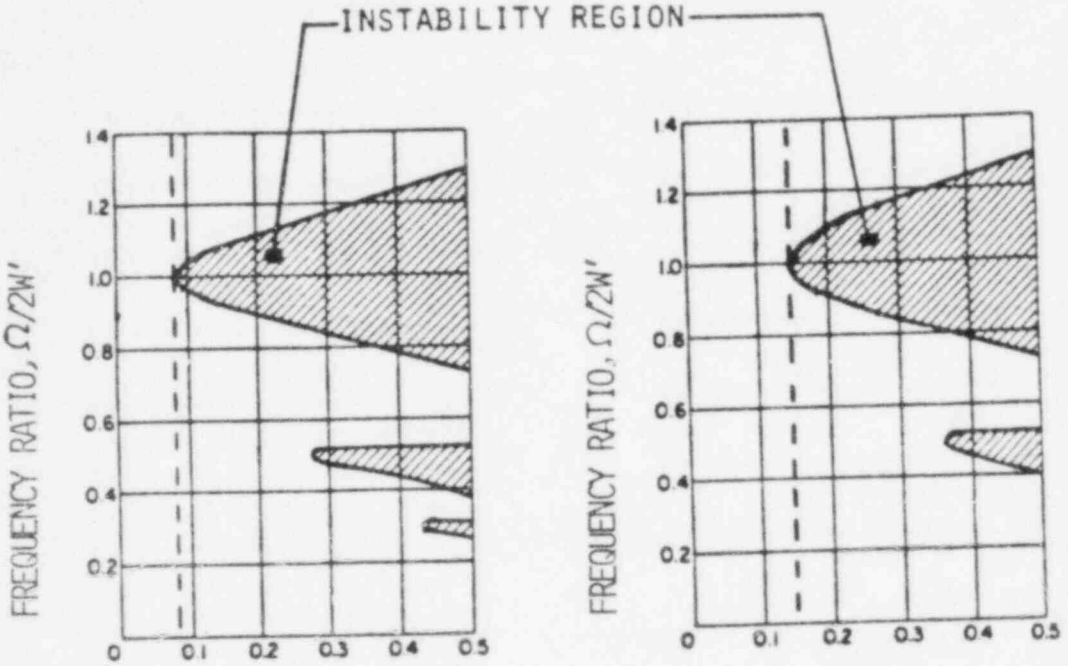
$$P = P_o + P_t \cos \Omega t$$

P_o = STATIC LOAD (TENSION OR COMPRESSION)
P_t = HARMONIC AXIAL LOAD
Ω = LOAD FREQUENCY
β = DAMPING RATIO
P_e = EULER BUCKLING LOAD

- UNSTABLE GROWTH OF TRANSVERSE MODAL DISPLACEMENTS POSSIBLE IF:
  - $P_t \geq 4\beta (P_o + P_e)$
  - Ω WITHIN CRITICAL RANGE

- DYNAMIC INSTABILITY ISSUE NOT REALLY APPLICABLE TO HANGER-TYPE SUPPORTS:
  - LOAD AMPLITUDE TOO SMALL
  - LOAD IS RANDOM NOT HARMONIC
  - LOAD DURATION TOO SHORT
  - STRUCTURE TOO COMPLEX

DYNAMIC INSTABILITY



FOR HANGER-TYPE SUPPORTS, DYNAMIC INSTABILITY WILL NOT OCCUR UNLESS $P_t \geq 2\mu(P_o + P_e)$:

OBE LOAD CASE

$P_t \geq 0.16\ (P_o + P_e)$

SSE LOAD CASE

$P_t \geq 0.28\ (P_o + P_e)$

EXPLICIT ANALYSIS SHOWS THAT WORST CASE LOADS LESS THAN CRITICAL VALUE OF P_t

2. AISC CODE COMPLIANCE (CONT.)

- o CODE RECOMMENDATION FOR TENSION MEMBERS:
  - L/R < 240 FOR MAIN MEMBERS
  - L/R < 300 FOR BRACING AND OTHER SECONDARY MEMBERS
- o CODE COMMENTARY DISCUSSES ABOVE RECOMMENDATION:

  "THE SLENDERNESS LIMITATIONS RECOMMENDED FOR TENSION MEMBERS ARE NOT ESSENTIAL TO THE STRUCTURAL INTEGRITY OF SUCH MEMBERS. THEY MERELY AFFORD A DEGREE OF STIFFNESS SUCH THAT UNDESIRABLE LATERAL MOVEMENT WILL BE AVOIDED. THESE LIMITS ARE NOT MANDATORY."
- o BOTH TEST AND ANALYSIS DEMONSTRATE THAT HANGER-SUPPORT TRANSVERSE DISPLACEMENTS ARE NEGLIGIBLE.
- o LONGITUDINAL DISPLACEMENTS ARE PROBABLY SMALL AS WELL AND ARE NOT A CONCERN IN ANY CASE

CONCLUSION:

L/R RECOMMENDATIONS FOR TENSION MEMBERS ARE NOT APPLICABLE.

3. ENGINEERING EVALUATION

- o FSAR COMMITMENTS AND CODE REQUIREMENTS ASIDE, REAL ISSUE IS STRUCTURAL INTEGRITY AND DEFLECTIONS OF HANGER-TYPE SUPPORTS

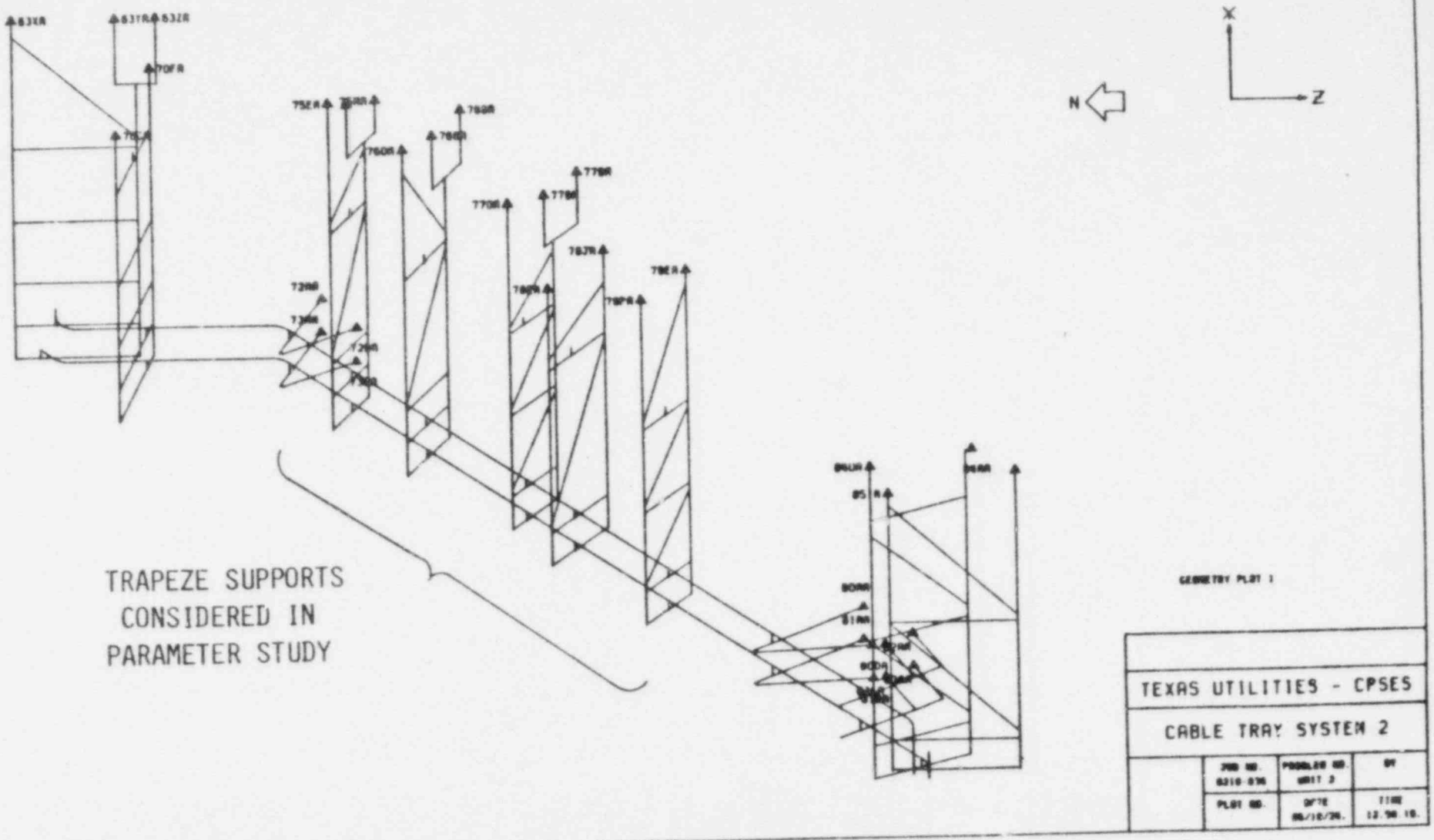
- o EXPLICIT DYNAMIC ANALYSES PERFORMED TO EVALUATE WORST CASE BEHAVIOR

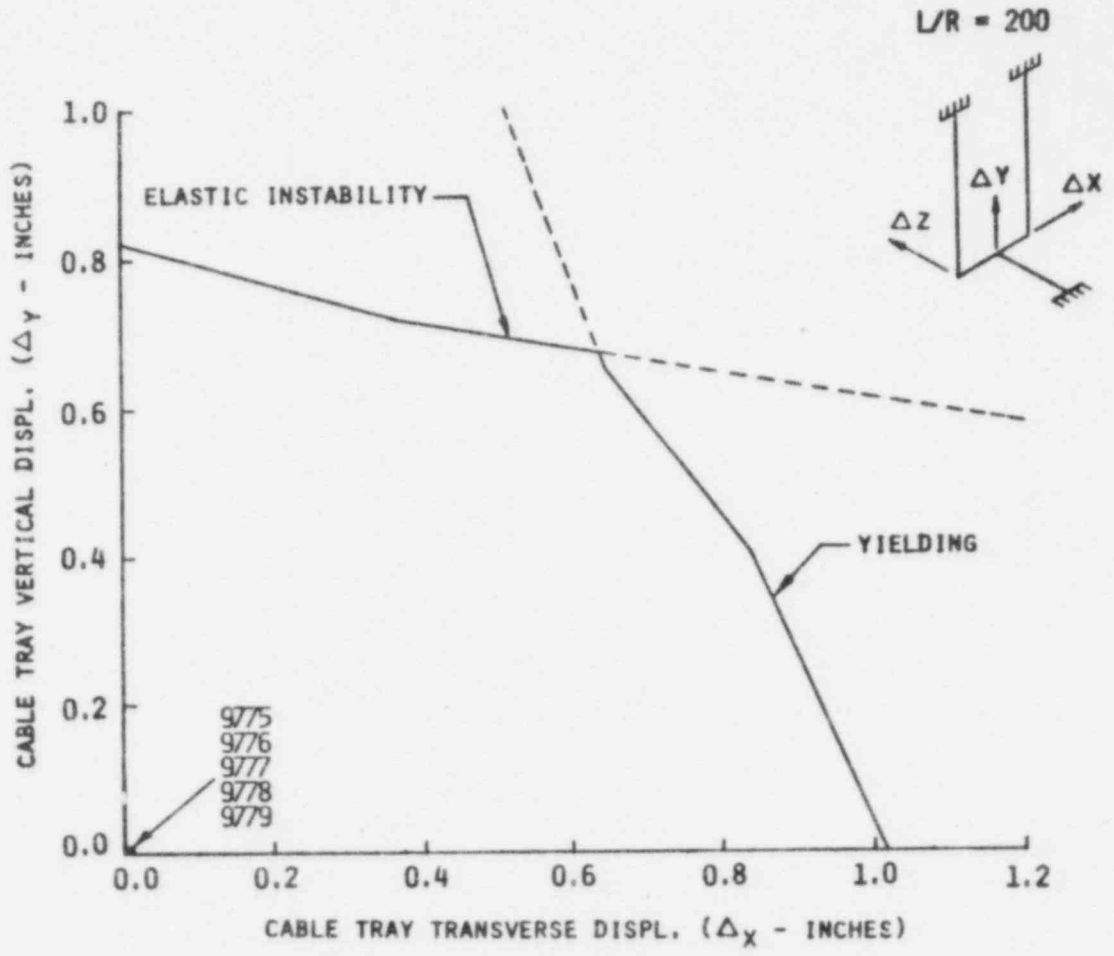
  - KL/R ASSUMED AS HIGH AS 394
  - MAXIMUM INPUT SPECTRA FROM TOP OF REACTOR BLDG.
  - FIVE TRAPEZE HANGERS IN A ROW (REAL SYSTEM)
  - RESULTS WITH AND WITHOUT ACTIVE CLIPS
  - RIGOROUS FAILURE ENVELOPES

- o RESULTS SHOW STRUCTURAL INTEGRITY IS INSENSITVE TO KL/R ISSUE

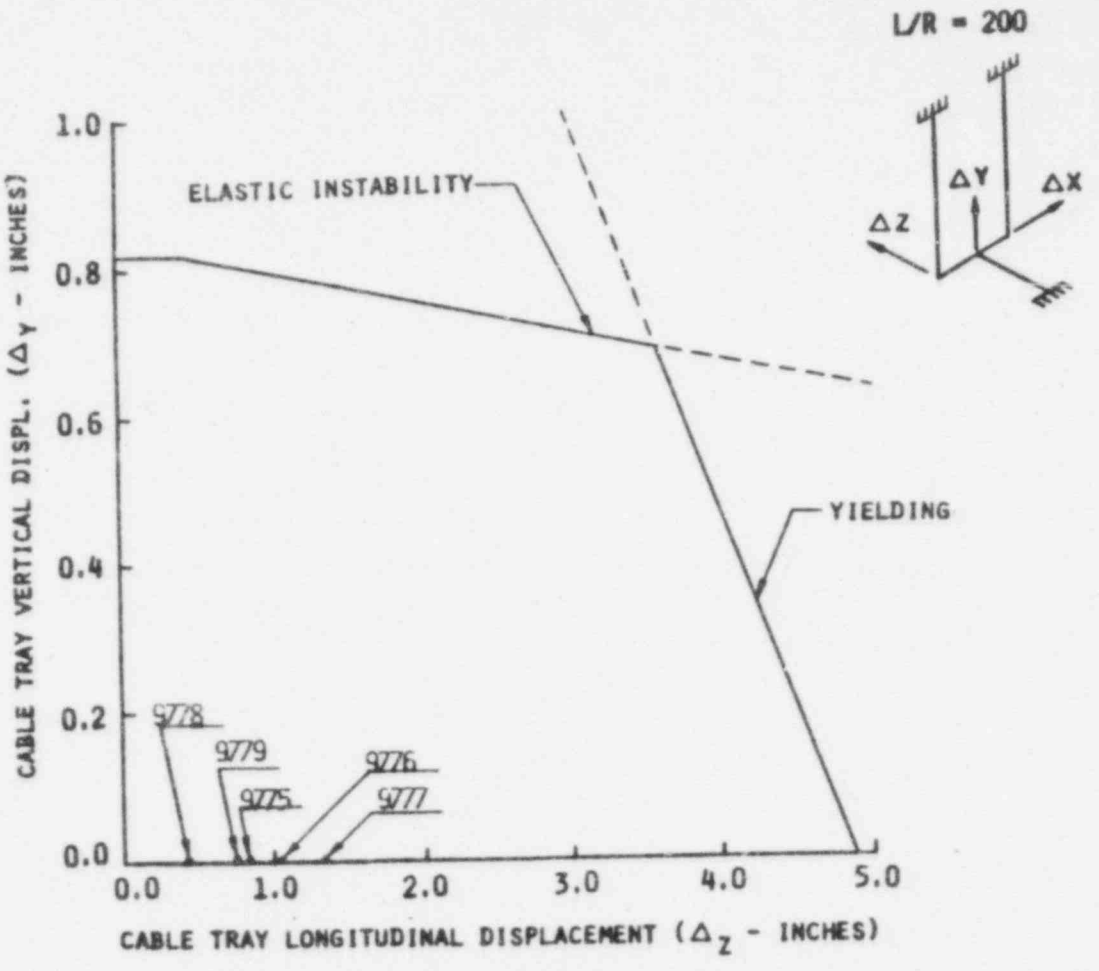
  - WORST CASE RESULTS WELL WITHIN WORST CASE FAILURE ENVELOPES
  - INTERACTION CHECK UNAFFECTED BY COMPRESSIVE LOADS
  - CAPACITY OF SUPPORTS DEPENDENT UPON CANTILEVER ACTION - NOT COLUMN ACTION

- o TRANSVERSE DISPLACEMENTS ARE NEGLIGIBLE FOR ALL KL/R

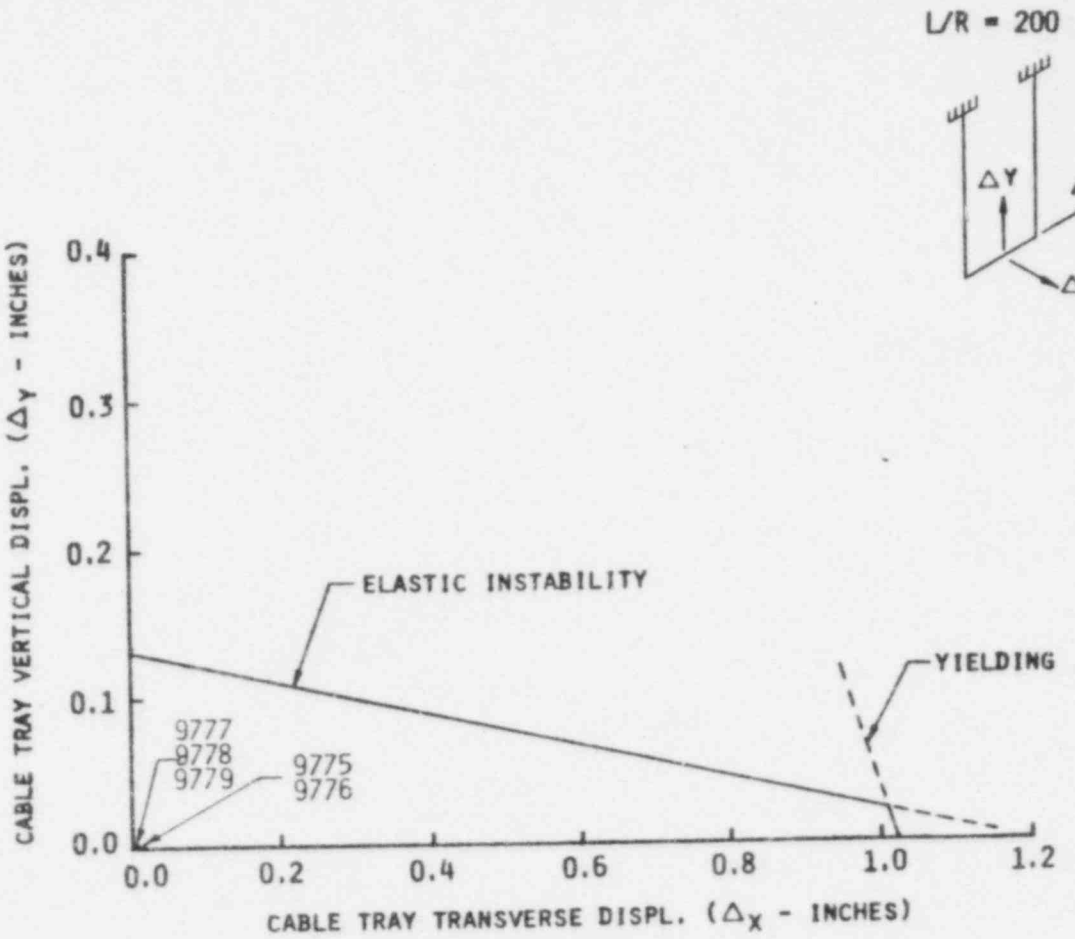

TRAPEZE SUPPORTS
CONSIDERED IN
PARAMETER STUDY
N
X
Z
GEOMETRY PLOT 1
TEXAS UTILITIES - CPSES
CABLE TRAY SYSTEM 2



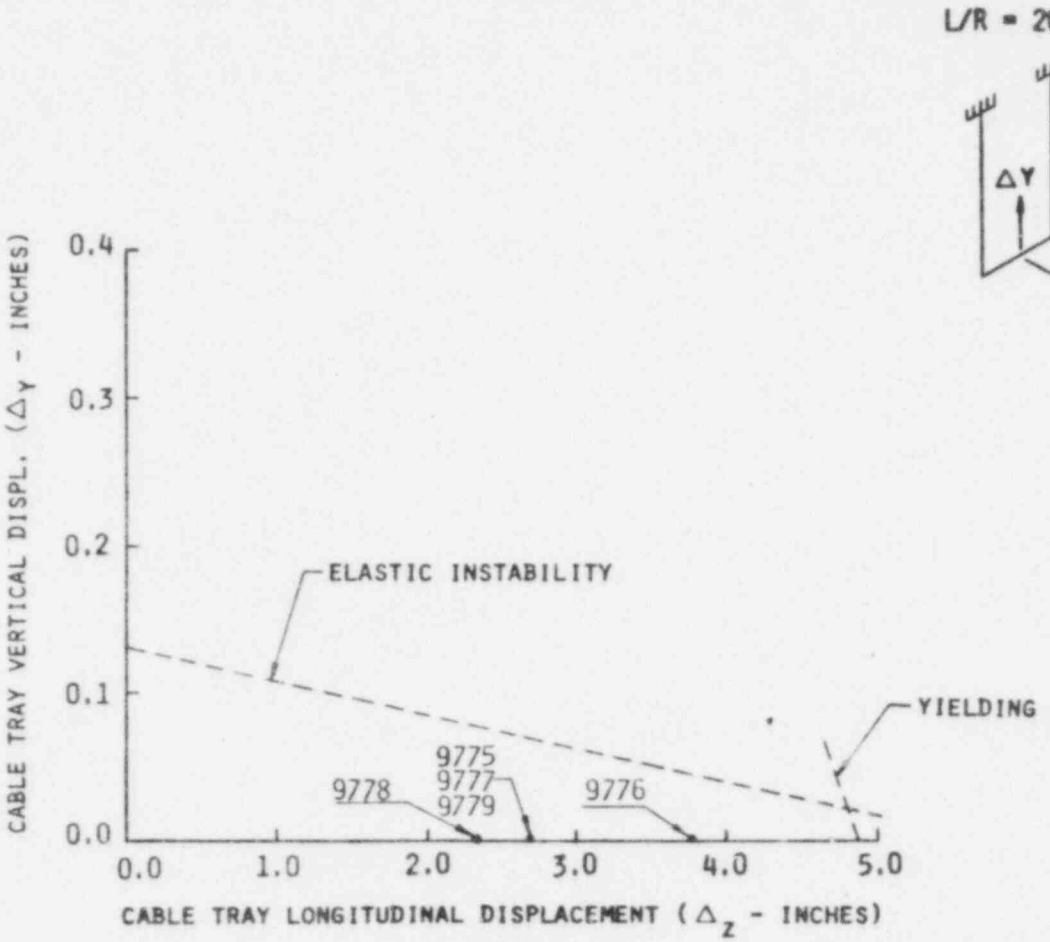
STRONG AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS ACTIVE)



WEAK AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS ACTIVE)



STRONG AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS NOT ACTIVE)



WEAK AXIS FAILURE ENVELOPE
WITH WORST CASE INTERACTION LOADS
(CLIPS NOT ACTIVE)

3.0 ENGINEERING EVALUATION (CONT.)

- UNLIKE TRUE COLUMNS, THE PRACTICAL CONSEQUENCES OF "BUCKLING" IN HANGER-TYPE SUPPORTS ARE NEGLIGIBLE
  - 50% DROP IN STIFFNESS
  - 30% DROP IN FREQUENCY
  - SMALL INCREASE IN DISPLACEMENTS
  - NO LOSS OF LATERAL/TENSILE STRENGTH
- FLEXIBLE STEEL STRUCTURES, SUCH AS HANGER-TYPE SUPPORTS, ARE THE LEAST VULNERABLE TO EARTHQUAKES OF ANY TYPE OF STRUCTURE - WITH OR WITHOUT KL/R LIMITS

CONCLUSION:

KL/R LIMITS ARE IRRELEVANT TO THE STRUCTURAL INTEGRITY OF HANGER-TYPE SUPPORTS

SUMMARY OF TUGCO POSITION

- o AISC CODE REQUIREMENTS NOT EXPLICIT BUT SUGGEST THAT KL/R ISSUE NOT APPLICABLE TO HANGER-TYPE SUPPORTS
  - SUPPORTS SHOULD BE CLASSIFIED AS TENSION MEMBERS
  - SHORT DURATION COMPRESSION NEGLIGIBLE IN COLUMN BUCKLING PROBLEMS
  - ONLY STATIC LOAD IS TENSION - KL/R LIMITS NOT REQUIRED
- o ENGINEERING EVALUATION VERIFIES THAT KL/R LIMITS NOT IMPORTANT
  - NEGLIGIBLE COMPRESSIVE LOADS
  - NO DYNAMIC INSTABILITY
  - STRUCTURAL BEHAVIOR IS CANTILEVER ACTION - NOT COLUMN ACTION
  - STRUCTURAL INTEGRITY NOT DEPENDENT UPON KL/R LIMIT
  - DEFLECTIONS NEGLIGIBLE FOR ALL KL/R

CONCLUSION:

KL/R LIMITATIONS SHOULD NOT BE APPLIED TO STRUCTURAL MEMBERS WHICH DO NOT EXPERIENCE STATIC COMPRESSION LOADS. KL/R LIMITATIONS WILL BE APPLIED TO MEMBERS WHICH EXPERIENCE STATIC AXIAL COMPRESSION.

Attachment 3

CPSES Cable Tray Supports

RLCA Preliminary Discussion on Limitation of Slenderness Ratios for Vertical Hanger Members

(Note: Quantitative Evaluation in Progress)

1. Issue

Are the vertical hanger members in CPSES cable tray supports subjected to the slenderness limitations in the AISC specification?

AISC Section 1.8.4:

> The slenderness ratio, Kl/r, of compression members shall not exceed 200.
>
> The slenderness ratio, l/r, of tension members, other than rods, preferably should not exceed:
>
> | | |
> |---|---|
> | For main members ..... | 240 |
> | For lateral bracing members and other secondary members ..... | 300 |

2. Discussion

2.1 Member Classification

AISC does not provide strict definitions of "compressive member" and "tensile member". In engineering practice, however, a structural member is considered a "compressive member" if its primary purpose is to resist loads by axial compression. This is consistent with the UBC definition of a column: "An element used primarily to support axial compressive loads and with a height at least three times its least lateral dimension."

The vertical hanger members are loaded primarily in tension, and to a relatively smaller extent in bending and shear, to support deadweight and seismic loads. If the combined seismic response in the upward and lateral directions is sufficiently high to overcome the tension due to deadweight, the hanger members will be subjected to short duration compressive "pulses". These pulses will have characteristics comparable to the impact effects addressed in the AISC Commentary (1.3.3) in reference to traveling crane loads:

"The increase in load, in recognition of random impacts, is not required to be applied to supporting columns, because the impact load effects (increase in eccentricities or increase in out-of-straightness) will not develop or will be negligible during the short duration of impact."

Thus, the hanger members should be classified as tensile members based on:

1. Primary function is to carry loads in tension.

2. Code recognition of low relative significance of impact-type loads for column stability considerations.

2.2 Validity of Buckling Curves at High Slenderness Ratios

The AISC Specification and Commentary do not provide any background or explanation for the slenderness limit of 200 for compressive members.

The SSRC (Structural Stability Research Council) does not recommend any upper slenderness limits, but indicates in recommended column strength curves the use of slenderness ratios in excess of 440. At these higher slenderness ratios the SSRC recommends the use of the unaltered Euler buckling curve for strength determination.

The safety factor specified for column buckling by the AISC is an increasing function of the slenderness ratio from a minimum of 1.67 to a value of 1.92 which stays constant for slenderness ratios above Cc (approximately 125). This constant factor of safety for slender columns eliminates one possible reason for the slenderness limitation in earlier code editions, where the column formulas contained implied safety factors that declined at higher slenderness ratios.

It is concluded that the arbitrary slenderness limitation of 200 is not applicable to the vertical hanger-type members.

2.3 Dynamic Versus Static Compressive Loads

A hanger member subjected to random short duration compressive loads will always return to a stable, tensile state when the transient compression has been removed.

Under short duration, random impact-type loads a structural member can be shown to remain stable under peak loads significantly exceeding the Euler buckling load.

Both of the above conditions tend to increase the conservatism involved in treating the analytically predicted maximum dynamic compressive load as an equivalent static load.

2.4 Slenderness Limitations for Tensile Members

The AISC specification states that the ratio l/r for main tensile members preferably should not exceed 240. In the commentary to the specification this recommendation is further clarified as follows:

"The slenderness limitations recommended for tension members are not essential to the structural integrity of such memnbers; they merely afford a degree of stiffness such that undesirable lateral movement ("slapping" or vibration) will be avoided. These limitations are not mandatory."

Thus, provided it can be demonstrated that undesirable or detrimental lateral movements will not occur, the recommended slenderness limitation for tensile members need not be applied.

References

1. AISC Specification, with Commentary, 8th Edition, 1978.

2. "Guide to Stability Design Criteria for Metal Structures", Third Edition. Structural Stability Research Council. John Wiley & Sons, 1976.

3. "Theory of Elastic Stability", Timoshenko and Gere.

4. "Dynamic of Structures", R.W. Clough and J. Penzien.

5. "Steel Structures, Design and Behavior", 2nd Edition, Harper & Row, 1980.