Abutment & Foundations

Design Modeling
&
Damage States

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Oct. 13 & 14, 2005
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From Past Earthquakes, it has been observed that :

(1) At stable sites, geotechnical modes of foundation failure are relatively rare despite predictions of failure due to inadequate geotechnical capacity (especially in overturning moment).

(2) Abutments, however are very vulnerable to earthquake damages.

The thrust of the foregoing discussions will focus on discussing modeling and damage states of abutments.

Example of Foundation Retrofit

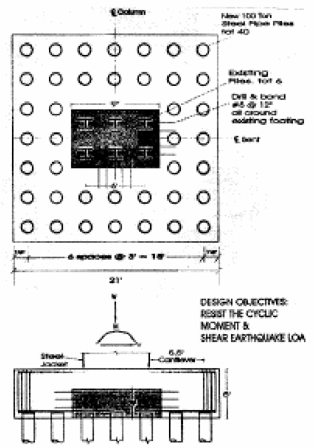

Figure 13: Example of Traditional Pile Footing Retrofit

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Abutments play a very important role on the seismic performance of a bridge from past historical earthquake experience. Therefore, a proper characterization of the abutment will be very important in Predicting the functionality of the bridge following a earthquake.

Most often, abutments can be repaired (at least temporary repairs to maintain traffic) shortly after the earthquake.

However, the abutment behavior has a very profound impact on the response the predicted performance of typical overcrossing structures And therefore, will play a very key role on how vulnerable would the bridge be during earthquake events.

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Basically, abutments are earth retaining systems, and abutment walls traditionally are designed following principles for designing free-standing retaining walls far away from massive structures.

Active earth pressure theories are commonly used for designing (e.g. 1/3 of effective overburden pressure) retaining walls.

Lam and Martin pointed out that such active pressure theories are invalid for abutment walls due to inertial loading of the massive bridge structure which would induce much higher passive earth pressure conditions.

At the moment, there is still lack of a way for designers to ensure no damages (predictable performances) of abutment systems. Hence virtually all California bridges are classified as non-essential bridges.

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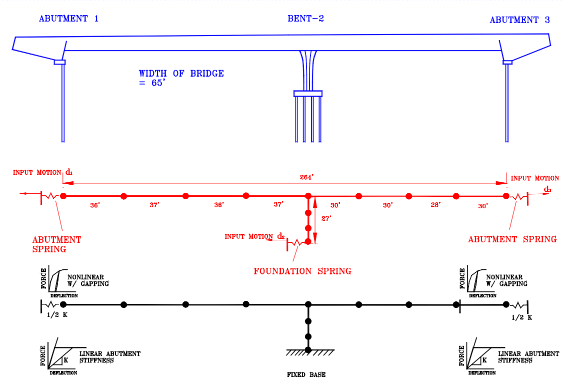

FIG. 1 SENSITIVITY STUDY OF LONGITUDINAL BRIDGE RESPONSE IN RELATION TO ABUTMENT MODELING

Current Bridge modeling analyses in Design implicitly accepts abutment damages :
The thrust would be to characterize the abutment load-deformation behavior, not on abutment Integrity issues, but to evaluate how the overall bridge (e.g. the column) performs.

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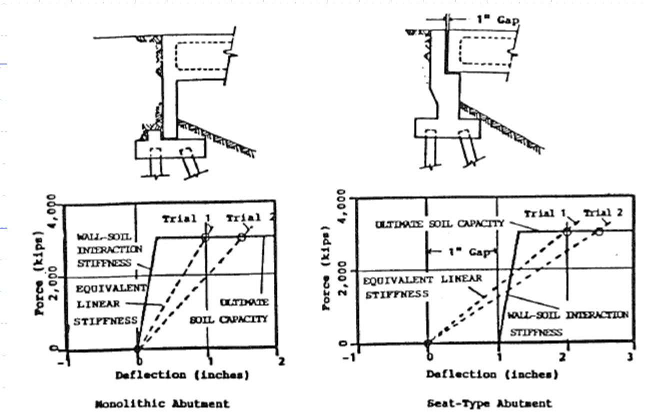

Historical Way to Model Abutment Stiffness on Conservative Basis.
Interative adjustment of abutment stiffness compatible with ultimate soil capacity

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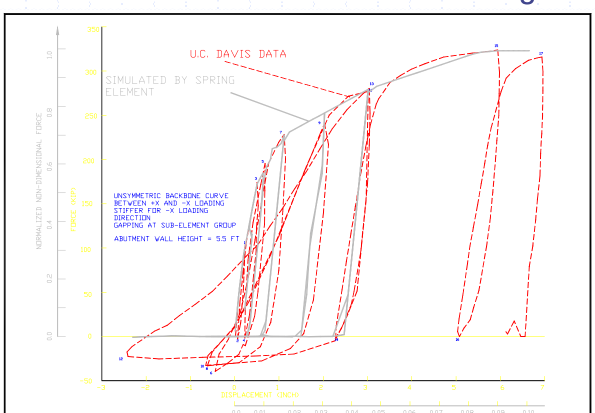

FIGURE 2. U.C. DAVIS ABUTMENT TEST DATA

Various research projects addressing abutment behavior
and steps to implement classical earth pressure theories in abutment modeling

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Caltrans

SECTION 7 - DESIGN

7.8 Abutments

7.8.1 Longitudinal Abutment Response

The linear elastic demand model shall include an effective abutment stiffness, K_{eff} that accounts for expansion gaps, and incorporates a realistic value for the embankment fill response. The abutment embankment fill stiffness is nonlinear and is dependent upon on the material properties of the abutment backfill. Based on passive earth pressure tests and the force deflection results from large-scale abutment testing at UC Davis, the initial embankment fill stiffness is $K_i \approx 20 \frac{\text{kip/in}}{\text{ft}}$ $(11.5 \frac{kN/mm}{m})$. The initial stiffness[15] shall be adjusted proportional to the backwall/diaphragm height, as documented in Equation 7.43.

Current updated abutment modeling practice in Caltrans

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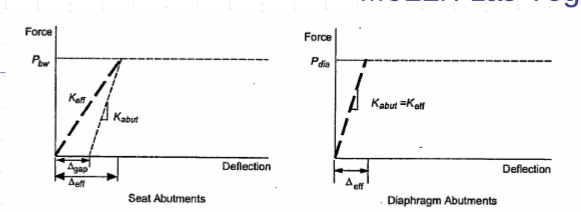

Figure 7.14A Effective Abutment Stiffness

K_{abut} is now set at 20 kip/in/ft wall width as opposed to 200 kip/in/ft originally.

Ultimate passive pressure capacity of soil is now set at 5 ksf for 5.5 ft wall height, but adjusted to various wall height w/ pressure varying linearly w/ height as compared to a constant value of 7.7 ksf in prior practice.

K_{eff} is now not iterated to the theoretical ultimate capacity, similar to way to model nonlinear bridge column bents. Former iterative method, leading to very large displacement (due also to simultaneously changing to crack EI) was deem to be too conservative.

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Various damage states of abutments:

(1) Most commonly observed damages are approach fill settlements, without associated structural damages. This can be repaired in days.

(2) Minor crackes to abutment wing walls which usually only compromises the long term performance, but still allow traffics on the bridge.

(3) Damages to abutment end-walls which can compromise the serviceability of the bridge, but temporary shoring was found to be effective to temporarily restore functionality in a short time (in days).

(4) Damages to foundations of the abutment which tend to result in loss of useage of the structure for an extended duration.

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Research Needs:

(1) Resolution of divergence in points of views between geotechnical and structural engineers.

(2) Innovations in the appropriate structural forms for abutments other than those conventionally suitable for free-standing retaining walls.

(3) Improved maintenances program to ensure that the backfills are in accordance with design assumptions. There are many cases where existing fills are washed away under the approach slabs.

(4) Needs for improved approach fill specifications and control measures.

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More Innovative Types of Abutments

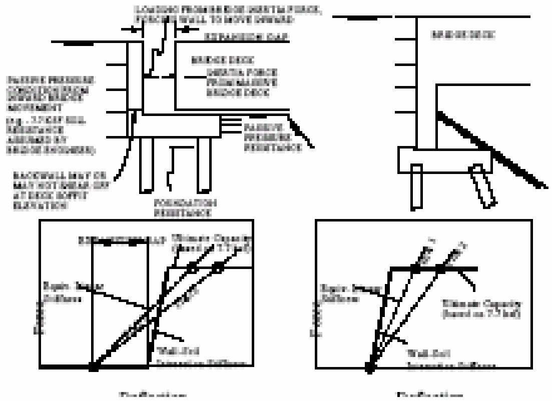

Figure 20. Abutment Types and Corresponding Load-Deflection Behavior