Seismic Performance of a Skewed Jointless Bridge

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Third International Workshop on Jointless Bridges
Hosted by International Association of Jointless Bridges
Seattle, WA, May 31-June 2, 2017

Comparison of Seismic Performance of Seat-Type and Integral Abutment Skew Bridges in Low Seismic Zones

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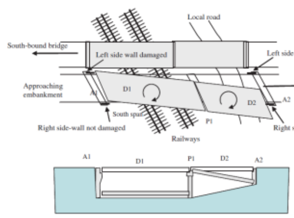
Outline

- Background
- Parameter study for connection forces and abutment reactions in skew bridges with seat-type abutments (STAB)
- Parameter study for abutment reactions in skew integral abutment bridges (IAB)
- Comparison between STAB and IAB
- Conclusions

Background: earthquake damage in skew bridges with seat-type abutments (STA)

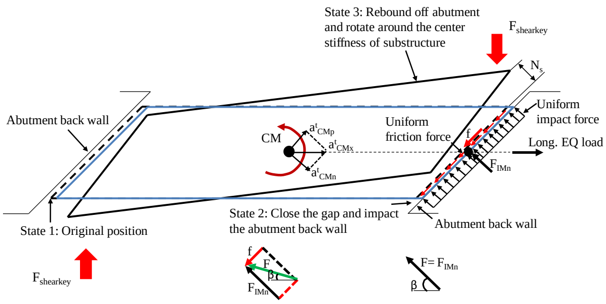


Hospital Overpass
2010 Maule Earthquake, Chile

Damage to Span D1

- Damage to abutment backwall due to superstructure pounding
- Shear keys were damaged at acute corners but remained intact at obtuse corners
- Girder unseating

Shear key forces at acute corners in symmetrical STA bridges



In numerical analysis, $\mu = 0$; therefore, f=0.0, leading to largest moment about CM and largest shear key force to prevent rotation.

Parameter study – F_{conn}, SZ 1, SDC A, and all single span bridges

Define design force ratio for each shear key:

$$\gamma = \frac{Design\ connection\ force, Fconn}{Vertical\ reaction\ due\ to\ tributary\ permanent\ dead\ load}$$

AASHTO LRFD (2012) and AASHTO Guide Specification (2011) specify:

$$\begin{cases} \gamma \geq 0.15 & if\ A_s < 0.05g \\ \gamma \geq 0.25 & if\ A_s \geq 0.05g \end{cases}$$

Table 3.10.6.1 (AASHTO LRFD)

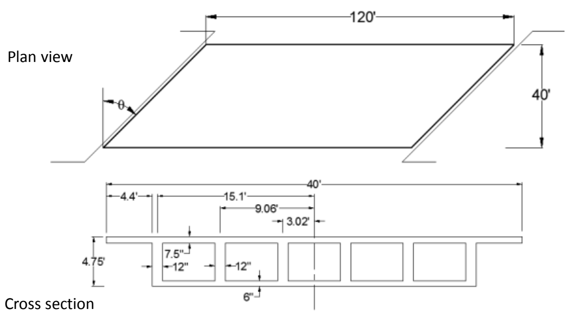
Acceleration Coefficient, S_{D1}	Seismic Zone
$S_{D1} \leq 0.15$	1
$0.15 < S_{D1} \leq 0.30$	2
$0.30 < S_{D1} \leq 0.50$	3
$0.50 < S_{D1}$	4

Table 3.5-1 (AASHTO GS)

Value of $S_{D1} = F_v S_1$	SDC
$S_{D1} < 0.15$	A
$0.15 \leq S_{D1} < 0.30$	B
$0.30 \leq S_{D1} < 0.50$	C
$0.50 \leq S_{D1}$	D

Parameter study - basic bridge geometry

Prototype bridge: single-span, seat-type abuts, T= 0.85 s, Δ_{temp} = 0.69 in

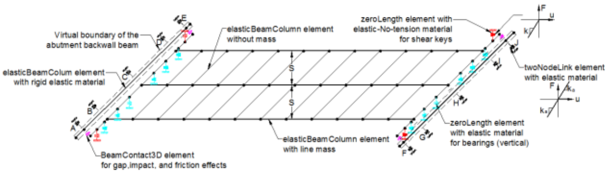


Parameter study - assumptions

- Skew angle, θ, increased from 0º to 60º in steps of 5º
- Four external shear keys assumed for single-span bridge, one at each corner. Under biaxial earthquake action, only two keys active at any one time. Therefore, vertical reaction due to tributary dead load at each active key is one half of total weight.
- Total weight of bridge is 1122 kips
- No gap between shear key and superstructure
- Elastic shear keys
- Rigid abutment backwall
- Typical abutment backfill resistance stiffness used (Caltrans SDC 2010)
- Span supported by 12 elastomeric bearings (six / abutment)

Parameter study - OpenSEES model (STAB)

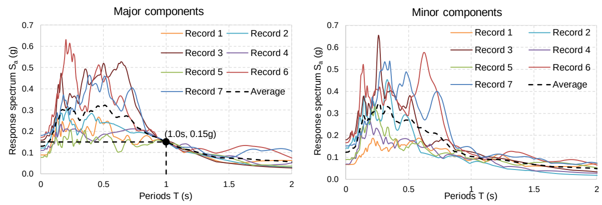
- Superstructure modeled by 3 parallel beams
- BeamContact3D element used to model impact and friction between bridge and abutment, coefficient of friction taken as 0.0
- zeroLength elements with elastic-No-tension material for shear keys
- zeroLength elements with elastic material for elastomeric bearings
- 5% damping in first translational and first rotational modes



Parameter study – ground motions

Record #	EQ	Year	Station	Distance (km)
1	Imperial Valley	1940	El Centro Array #9	6.09
2	San Fernando	1971	Castaic	22.63
3	Friuli, Italy	1976	Tolmezzo	15.82
4	Northridge	1994	Sun Valley	10.05
5	Northridge	1994	Century City	23.41
6	Loma Prieta	1989	Anderson Dam	20.26
7	Darfield, New Zealand	2010	Kaiapoi North School	30.53

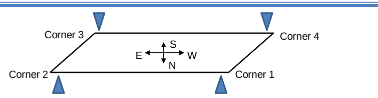
Major component in long. direction; minor component in trans. direction



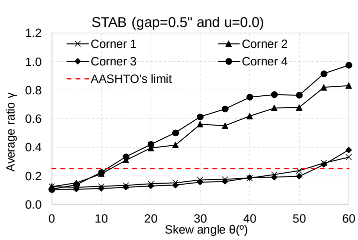
Average results from 7 ground motions used to draw conclusions

Parameter study – $F_{shearkey}$ (STAB)

L=120 ft
B=40 ft



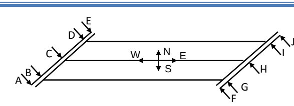
$$\gamma = \frac{Design\ shear\ key\ force, Fshear\ key}{Vertical\ reaction\ due\ to\ tributary\ permanent\ dead\ load}$$

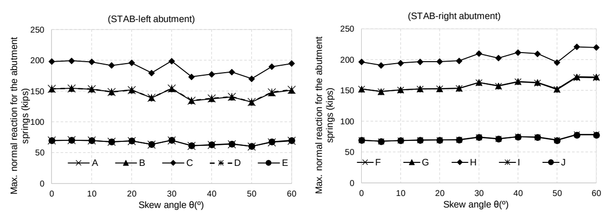


- Larger shear key forces at acute corners than the obtuse corners
- Shear keys forces at acute corners exceed AASHTO's design value (γ=0.25) for θ ≥ 15º

Parameter study – abutment reactions (STAB)

L=120 ft
B=40 ft

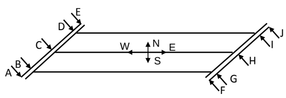


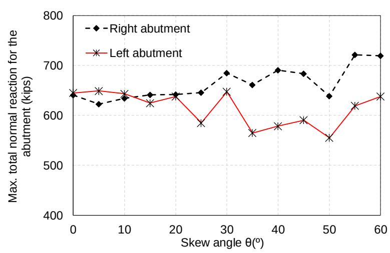


In-plane rotation prevented by shear keys

Parameter study – total abut. reactions (STAB)

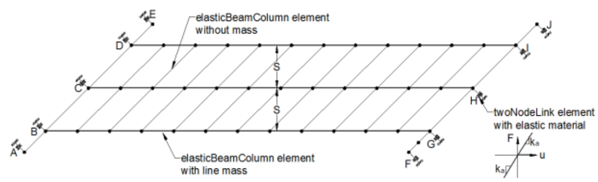
L=120 ft
B=40 ft





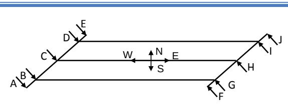
Parameter study-OpenSEES model (IAB)

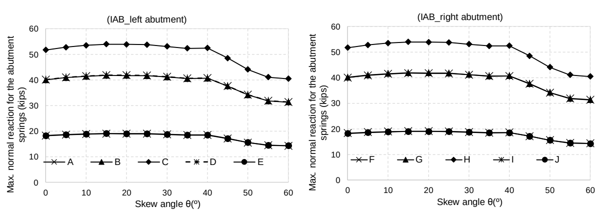
- Backfill resistance of each abutment modeled by 5 springs connected directly to the superstructure and stiffness properties taken the same as STAB



Parameter study – abutment reactions (IAB)

L=120 ft
B=40 ft

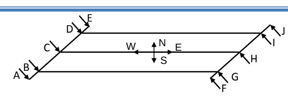


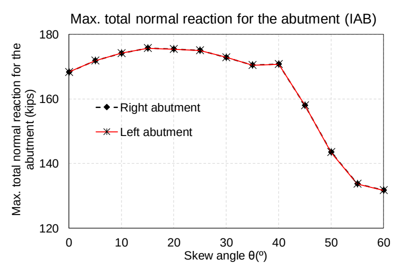


Symmetric response and no in-plane rotation

Parameter study – total abut. reactions (IAB)

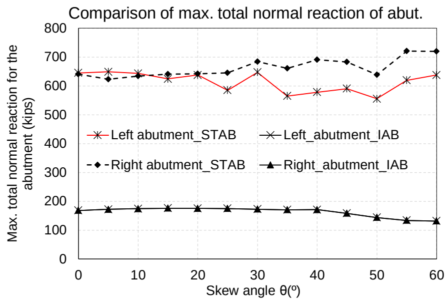
L=120 ft
B=40 ft





Same reaction at each abutment due to symmetry

Parameter study – comparison



Maximum total normal reaction of abutment backfill for STAB is up to 4 times higher than that for equivalent IAB

Conclusions

- Shear keys in STA Bridges are subject to larger forces at acute corners than at the obtuse corners, when the longitudinal gap closes and superstructure pounding occurs.
- Shear key forces and backwall pressures are much larger in STA Bridges than in equivalent IA Bridges, leading to heavier seats and backwalls in STA Bridges (pile sizes remain the same).
- [Larger shear keys are required at the acute corners of STA Bridges than required by current AASHTO specifications.]

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