

Connections between Steel and Concrete

Volume Two

Stuttgart, Germany

10-12 September 2001

Organised by
University of Stuttgart

Co-sponsored by
ACI, fib, IABSE

Edited by R. Buehler

- HOCHSCHULE
 - LIECHTENSTEIN
- Bibliothek

K. I. Ivi'-i.¹^.-. ...i j . .i ;,

RILEM Publications S.A.R.L.
The Publishing Company of RILEM



Contents

VOLUME ONE

Preface

PART ONE: KEYNOTE LECTURES

- 1 **Where structural steel and concrete meet** 1
J. W. B. Stark and D. A. Hordijk
- 2 **Fastening technique - Current status and future trends** 11
R. Eligehausen, I. Hofacker and S. Lettow

PART TWO: DESIGN

- 3 **Anchoring to concrete: the new ACI approach**
J. E. Breen, E.-M. Eichinger and W. Fuchs (Keynote Lecture)
- 4 **Evolution of fastening design methods in Europe** 45
W. Fuchs (Keynote Lecture)
- 5 **Probabilistic calibration of design methods**
R. E. Klingner (Keynote Lecture)
- 6 **Current status of post-installed anchor application in Japan** 72
R. Tanaka (Keynote Lecture)
- 7 **Design method for splitting failure mode of fastenings** 80
J. Asmus and R. Eligehausen
- 8 **Behaviour and design of fastenings of shear lugs in concrete**
H. Michler and M. Curbach
- 9 **Safety relevant aspects for torque controlled expansion anchors**
H. Gassner and E. Wisser
- 10 **Study on standard test methods for post-installed anchors**
Y. Hosokawa, K. Nakano, Y. Oohaga, S. Usami and K. Imai
- 11 **Static behavior of anchors under combinations of tension and shear** 118
D. Lotze, R. E. Klingner and H. L. Graves, III

- 12 Improved structural model for channel bars with more than two anchors**
J. Kraus, J. Ozbolt and R. Eligehausen
- 13 Anchors in low and high strength concrete** *1
/ J. Kunz, Y. Yamamoto and M. Berra
- 14 Development of common uniform regulations in Europe for the assessment of metal anchors**
K. Laternser
- 15 Behavior of multiple-anchor fastenings subjected to combined tension/shear loads and bending moment**
L. Li and R. Eligehausen
- 16 Load bearing capacity of torque-controlled expansion anchors**
L.Li
- 17 Behaviour and design of anchors close to an edge under torsion**
R. Mallee
- 18 Fixings with anchors: concerning relevant base plate thickness**
R. Mallee and F. Burkhardt
- 19 Installation verification of mechanical and adhesive anchors**
L. Mattis
- 20 Steel capacity of headed studs loaded in shear**
N. S. Anderson and D. F. Meinheit
- 21 The analysis of fastener strength using the limit state approach**
J. J. Melcher and M. Karmazinova
- 22 Behavior of shear anchors in concrete: statistical analysis and design recommendations**
H. Muratli, R. E. Klingner and H. L. Graves, III
- 23 Study on shear transfer of joint steel bar and concrete shear key in concrete connections**
K. Nakano and Y. Matsuzaki
- 24 Performance of undercut anchors in comparison to cast-in-place headed studs**
P. Pusill-Wachtsmuth

25	Shear anchoring in concrete close to the edge N. Randl and M. John	251
26	Behavior of tensile anchors in concrete: statistical analysis and design recommendations M. Shirvani, R. E. Klingner and H. L. Graves, III	261
27	Performance of single anchors near an edge under varying angles of loading R. E. Wollmershauser, U. Nestler and V. Smith	272
28	The prequalification of anchors in the United States of America: past, present and future R. E. Wollmershauser	288
29	On the ratio of plate thickness to stud diameter for steel concrete stud shear connectors H. D. Wright, A. Elbadawy and R. Cairns	290
30	Incorporation of the size effect and other factors in strength design of concrete fastenings, in the context of the CEB Design Guide V. I. Yagust and D. Z. Yankelevsky	300

PART THREE: DURABILITY/FIRE

31	Corrosion behavior of materials in fixing applications N. Arnold	313
32	Behaviour of post-installed anchors in case of fire K. Bergmeister and A. Rieder	329
33	Durability of galvanized, post-installed fasteners to concrete K. Menzel and B. Hagmayer	329
34	Durability of stainless steel connections with respect to corrosion U. Nurnberger	336
35	Fire resistance of steel anchors in concrete M. Reick	341

PART FOUR: BONDED ANCHORS

36	Anchoring with bonded fasteners R. A. Cook and R. C. Konz (Keynote Lecture)	161
----	--	-----

- 37 Experimental study on performance of bonded anchors in the low strength reinforced concrete**
T. Akiyama, Y. Yamamoto, S. Ichihashi and T. Katagiri
- 38 Behavior of grouted anchors**
R. A. Cook, N. A. Zamora and R. C. Konz
- 39 Long time load-carrying capacity of bonded anchors**
L. Elfgrén, G. Danielsson, I. Holm and G. Soderlind
- 40 Transmission of shear loads with post-installed rebars**
J. Kurtz
- 41 Design of anchorages with bonded anchors under tension load**
B. Lehr and R. Eligehausen
- 42 Load bearing behavior and design of single adhesive anchors**
J. Meszaros and R. Eligehausen
- 43 Rebar anchorage in concrete with injections adhesive**
M. Reuter, T. Greppmeir and F. Munger
- 44 Investigations on bonding behaviour of tie reinforcements in historic masonry**
M. Raupach, J. Brockmann, A. Domink and M. Schurholz
- 45 Actual trends in chemical fixings: from capsule to injection systems**
J. Schatzle
- 46 Performance of bonded anchors in dependence of installation conditions, state of cure - Deformation behavior at elevated temperatures**
G.W. Ehrenstein and A. Tome
- 47 Study on the performance evaluation of the new capsule typed bonded anchor**
M. Yonetani, A. Fukuoka and Y. Matsuzaki

PART FIVE: SEISMIC BEHAVIOUR

- 48 Seismic behavior of connections between steel and concrete**
J. O. Jirsa (Keynote Lecture)
- 49 Tests on connectors for seismic retrofitting of concrete and masonry structures in Mexico**
S. M. Alcocer and L. Flores

50	Design and construction of heavy industrial anchorage for power-plants P. J. Carrato and W. F. Brittle	491
51	Dynamic behavior of single and double near-edge anchors loaded in shear J. Hallowell Gross, R. E. Klingner and H. L. Graves, III	498
52	Post-installed rebar connections under seismic loading I. Hofacker and R. Eligehausen	509
53	An evaluation of tensile capacity of anchor system in nuclear power plants by actual model tests J.-B. Jang, S.-K. Woo; Y.-P. Suh and J.-R. Lee	521
54	Structural behavior of SRC Column - RC beam joint under monotonic and cyclic load S-H. Lee, Y.-K. Ju, S.-C. Chun and D.-Y. Kim	531
55	Dynamic behavior of tensile anchors to concrete M. Rodriguez, D. Lotze, J. Hallowell Gross, Y.-g. Zhang, R. E. Klingner and H. L. Graves, III	541
56	Test methods for seismic qualification of post-installed anchors J. F. Silva	551
57	Safety concept for fastenings in nuclear power plants T. M. Sippel, J. Asmus and R. Eligehausen	564
58	Experimental study on seismic performance of beam members connected with post-installed anchors R. Tanaka and K. Oba	576
59	Shallow shear anchor bolts for structural seismic strengthening of columns with wing wall Y. Yamamoto, Y. Hattori, T. Koh and M. Kato	586
60	Seismic response of multiple-anchor connections to concrete Y.-g. Zhang, R. E. Klingner and H. L. Graves, HI	596

PART SIX: NUMERICAL SIMULATION

tUi

- 61 Smearred fracture Finite Element analysis of reinforced concrete structures - Theory and examples**
J. Ozboft (Keynote Lecture)
- 62 Numerical and experimental investigations of the splitting failure mode of fastenings**
J. Asmus and J. Ozbolt
- 63 Three dimensional modeling of an anchorage to concrete using metal anchor bolts**
H. Boussa, G. Mounajed, B. Mesureur and J.-V. Heck
- 64 Influence of bending compressive stresses on the concrete cone capacity**
M. Bruckner, R. Eligehausen and J. Ozbolt
- 65 ATENA - An advanced tool for engineering analysis of connections**
V. Cervenka , J. Cervenka and R. Pukl
- 66 A computational model for double-head studs**
A. Haufe and E. Ramm
- 67 Behavior and design of fastenings with headed anchors at the edge under arbitrary loading direction**
J. Hofmann, J. Ozbolt and R. Eligehausen
- 68 Evaluation of a bridge deck strengthening with shear connectors: Finite Element analysis and experimental results**
A. J. Leite

VOLUME TWO

- 69 Numerical analysis of group effect in bonded anchors with different bond strengths**
Y.-J, Li and R. Eligehausen
- 70 Simulation of fastening systems utilizing cbchemical and mechanical anchors**
J. Nienstedt, R. Mattner, U. Nestler and C. Song
- 71 Headed stud anchor - cyclic loading and creep-cracking interaction of concrete**
J. Ozbolt, J. Hofmann and R. Eligehausen

72	Numerical investigations of headed studs with inclined shoulder	729
	P. Pivonka, R. Lackner and H. A. Mang	
73	Simulating a response of connections	747
	R. Pukl, J. Cervenka and V. Cervenka	

PART SEVEN: APPLICATIONS

74	Non-supported crash barriers - Proof of the concrete resistances according to the concrete-capacity-method	759
	J. Buhler	
75	Reconstruction of multi-layer-walls	766
	E. Dereser and J. Buhler	
76	Load carrying capacity of fasteners in concrete railway sleepers	774
	H. Thun, S. Utsi, L. Elfgren, P. Nilsson and B. Paulsson	
77	Anchorage with headed bars in exterior beam-column joints	785
	J. Hegger and W. Roeser	
78	Halfen HDB-S bars as shear reinforcement in slabs and beams	795
	J. Hegger, K. Frohlich, R. Beutel and W. Roeser	
79	Behaviour of fasteners in concrete with coarse recycled concrete and masonry aggregates	805
	D. A. Hordijk and R. van der Pluijm	
80	Regarding strength of anchor bolts used for precast concrete curtain wall fasteners	815
	H. Kawamura, T. Otobe and S. Oka	
81	New method of reconstruction - Strengthening of old buildings	825
	M. Marjanishvili, T. Zuzadze, D. Ramishvili and A. Lebanidze	
82	Fastening in masonry	836
	A. Meyer and T. Pregartner	
83	Study on design method of joint panels for hybrid railway rigid-frame bridges	847
	H. Nishida, K. Murata and T. Takayama	
84	Tension stiffening model based on bond	857
	M. A. Polak and K. Blackwell	



- 85 Over-cladding of existing concrete buildings using cold formed light steel sections and composite cladding panels**
S. O. Popo-Ola, R. M. Lawson and P. J. Sullivan
- 86 Redundant structures fixed with concrete fasteners**
M. Rd3le and R. Eligehausen
- 87 Numerical and experimental analysis of post-installed rebars spliced with cast-in-place rebars**
H. A.Spieth, J. Ozbolt. R. Eligehausen and J. Appl
- 88 Dowel action of titanium bars connecting marble elements**
E. Vintzileou and C. Papadopouios
- 89 Case study - Application of high strength post-tensioned rods for anchoring aerial tram structures to rock**
G. P. Wheatley

PART EIGHT: SPECIAL FASTENERS

- 90 Behaviour and design of fastenings with concrete screws**
J. H. R. Kilenzlenand T. M. Sippel
- 91 Behaviour and design of anchors for lifting and handling in precast concrete elements**
D. Lotze
- 92 Behaviour of plastic anchors in cracked and uncracked concrete**
T. Pregartner and R. Eligehausen

PART NINE: BRIDGES

- 93 Testing of a dowel connection for a bridge with a concrete deck and a sandwich panel truss structure**
H. Blontrock, L. Taerwc, A. Nurchi, J. Vantomme, C. De Roover, J. Wastiels and K. Croes
- 94 A new step forward for composite bridges j.i'...nr<in rtaiwb ft«-**
The Bras de la Plaine Bridge
E. Barlet, G. Causse and J.-P. Viallon
- 95 Anchorage of the steel elements to the concrete piers at the specific pipe bridges over a Danube Bay in Budapest**
B.

96	Behavior and design of steel girder-to-concrete column connection for a cantilever-construction highway bridge L. Huang, H. Hikosaka, M. Shimozono and K. Akehashi	982
PART TEN: COMPOSITE STRUCTURES		
97	Recent developments and chances composite structures U. Kuhlmann (Keynote Lecture)	905
98	Design of lying studs with longitudinal shear force U. Breuninger	15
99	Studies on the ductility of shear connectors when using high-strength steel and high-strength concrete J. Hegger, G. Sedlacek, P. Ddinghaus and H. Trumpf	1025
100	Experimental investigations on the behaviour of strip shear connectors with powder actuated fasteners M. Fontana, H. Beck and R. Bartschi	1046
101	Design concept of nailed shear connections in composite tube columns G. Hanswille, H. Beck and T. Neubauer	1056
102	An experimental study on shear characteristics of Perfobond strip and its rational strength equations Y. Ushijima, T. Hosaka, K. Mitsuki, H. Watanabe, Y. Tachibana and H. Hiragi	1066
103	Behavior of lying shear studs in reinforced concrete slabs U. Kuhlmann and K. Kurschner	1076
104	Composite bridge with compression joint - Connection concrete end slab to steel girder - Finite Element method M. V. Lammens	1086
105	Perfo-bond connection and tests S. Poot	1095
106	Development and application of saw-tooth connections for composite structures J. Schlaich	1105
107	Geometry, behaviour and design of high capacity saw-tooth connections V. Schmid	1119

- 108 Composite bridge with compression joints - Connection concrete end slab to steel girder- Dowels divided in groups
D. Tuinstra

PART ELEVEN: FATIGUE

- 109 The fatigue behaviour of the shear connection in the hogging region of steel and concrete composite continuous beams under realistic loading
H. Bode and A. Leffer
- 110 Influence of fatigue loads in tension on short cast-in-place anchors in concrete
E. Cadoni
- 111 A test proposal for fatigue experimental studies on stud shear connectors
N. Gattesco and E. Giuriani
- 112 Innovative interface systems for steel-girders/concrete-deck connection
M. K. Tadros, S. S. Badie and A. M. Girgis

PART TWELVE: CONNECTIONS

- 113 Non-linear analysis of steel-concrete composite beams: a Finite Element model
C. Faella, E. Martinelli and E. Nigro
- 114 Connections between prestressed concrete bridge decks and composite bridge decks - Hybrid construction
D. Jankowski, O. Fischer and M. Matthes
- 115 Anchorage behavior of 90-degree hooked beam bars in reinforced concrete wall-beam intersections
O. Joh, Y. Goto and A. Kitano
- 116 Embedded steel bearings instead of concrete nibs
M. R. Kintscher
- 117 Anchorage zone in a steel-concrete composite slab with unbonded tendons
H. Koukkari
- 118 Connections for continuous framing in precast concrete structures
G. Krummel

119	Standoff screws as shear connectors for composite trusses: push-out test results and analysis	1240
	J. R. U. Mujagic, W. S. Easterling and T. M. Murray	
120	Experimental study on a new joint for prestressed concrete composite bridge with steel truss web	1250
	K. Furuichi, M. Yamamura, H. Nagumo and K. Yoshida	
121	Development and application of embedded connection	1260
	M. Sakurada, T. Yoda, K. Ashiduka and T. Ohura	
122	Design and construction of a concrete-filled steel tube joint	1270
	S. P. Schneider, D. R. Kramer and D. L. Sarkkinen	
123	Friction slipping behavior between concrete steel - Aiming the development of bolted friction-slipping joint	1281
	T. Yoshioka and M. Ohkubo	

PART THIRTEEN: EXPERIMENTAL STUDIES

124	Art experimental study on the connection joints between steel girder and reinforced concrete column with various types of embedded load transferring plates	1293
	N. Ando, I. Nishimura and K. Kamo	
125	Low-cycle fatigue Behaviour of Pull-Push Specimens with Headed Stud Shear Connectors	1303
	S. Erlicher, O. S. Bursi and R. Zandonini	
126	Static tests on various types of shear connectors for composite structures	1313
	H. C. Galjaard and J. C. Walraven	
127	Structural monitoring of hybrid specimens at early age using fibre optic sensors	1323
	B. Glisic and D. Inaudi	
128	Development of innovative composite system - Between steel and concrete members	1333
	K. Kitagawa, H. Watanabe, Y. Tachibana, H. Hiragi and A. Kurita	
129	An experimental study on the bond-slip relationship between the concrete and steel with stud	1343
	K. Konno, A. Farghaly and T. Ueda	

130 The behavior of beam-to-box column connection of CFT with air cavity 135
 M.-J. Yee, M.-S. Choi, **J.-H. Kim** and S.-W. Jun

131 Sheet reinforcement 136
 O. Matthaei, H.-P. Andra and N. V. Tue

PART FOURTEEN: SLIM FLOOR STRUCTURES

132 Composite girders of reduced height 137
 U. Kuhlmann, J. Fries and A. Rieg

133 Innovative development of light steel composites in buildings 138
R. M. Lawson, S. O. Popo-Ola and D. N. Varley

134 Intentional and unintentional shear connections in shallow floor composite structures 139
 M. V. Leskela

Author Index 140