ADVANCES IN BRIDGE DESIGN AND CONSTRUCTION USING RECENT IMPROVEMENTS IN RAPID CONSTRUCTION OF TALL SEISMIC RESISTANT BUILDINGS IN CALIFORNIA

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The economic need to rapidly design and construct tall earthquake resistant buildings in California, USA, has resulted in advancement of both design and construction technology for concrete bridges. After extensive development and testing for more than a decade, the world's tallest precast concrete building in a zone of highest seismicity, a 39-story building, has been construction in San Francisco, using a new type of concrete reinforcement, Welded Reinforcement Grids (WRG), that saves cost, time and labor. Also in San Francisco is a recently completed 42-story building that, by using the WRG reinforcement system, replaced 32 separate pieces of conventional confinement reinforcement with one-piece WRG.

A 1.2 million S.F. 24-story building in Long Beach, California USA is being constructed with 75% reduction of labor with the rapid assembly of WRG reinforcement cages.

Testing at five universities and national laboratories of Canada and the USA has shown that structures, when designed with this new reinforcement, will have little to no damage during a violent earthquake. The tests also proved that the structures, designed using the new WRG reinforcement product, required significantly less concrete and reinforcement steel.

The success of the Welded Reinforcement Grids in tall California earthquake resistant buildings has caused a great interest by structural engineers in their use in other types of structures. Fatigue testing of WRG in Lightweight High Performance Concrete (LHPC) is planned in preparation for use of WRG in LHPC in segmental bridges where the dimensional accuracy of ±1/8" (3mm) allows use of automation of the WRG reinforcing cage assembly.

KEY WORDS
Welded Reinforcement Grids, WRG, Earthquake Resistant, Rapidly Construct, Tall Earthquake Resistant Building, Reinforcement Steel, Precast, Segmental Bridges, Bridge Construction

INTRODUCTION

Design Engineers have learned that close teamwork between researchers and members of the Design/Construct team results in advances in both design and construction.

WELDED REINFORCEMENT GRIDS

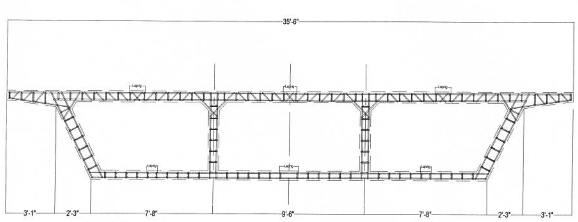

Figure 1 - Proposed Segmental Bridge

For more than a decade, Researchers and Design/Construct teams have been developing a new type of proprietary confinement reinforcement called BauGrid® Welded Reinforcement Grids.

Concrete members reinforced with BauGrid® WRG have been tested at five universities and national laboratories of Canada and the USA. Fatigue testing of WRG in Lightweight High Performance Concrete (LHPC) is planned in preparation for use of WRG in LHPC segmental bridges.

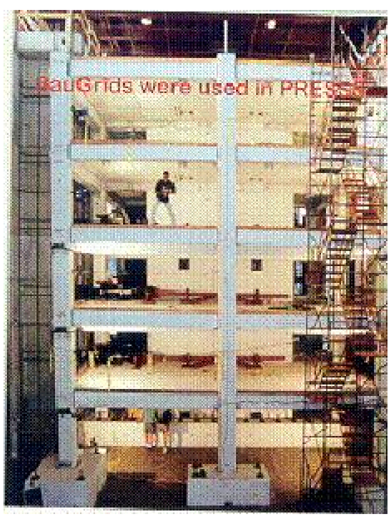

Figure 2 - Five story scale model test frame

BAUGRID® WRG REINFORCED PRECAST STRUCTURES

After extensive testing of BauGrid® WRG reinforced precast concrete members, a one-fifth scale five-story frame was tested at the University of California, San Diego. These tests proved that a tall precast concrete building could be constructed in a zone of highest seismicity. They also showed that there will, very likely, be little or no damage to the structure even after a violent earthquake.

Figure 3 - 39-story Precast Paramount Building

THE PARAMOUNT BUILDING IN SAN FRANCISCO

Based upon the results of these tests, the world's tallest precast building in a zone of highest seismicity was constructed in San Francisco by Charles Pankow Builders, Ltd. using the designs of Robert Englekirk, Structural

Engineer.[1] The precast frame members of this 39-story structure are reinforced with BauGrid® WRG.

THE ST. REGIS MUSEUM TOWER

Figure 4 - 42-story St. Regis Museum Tower

Also in San Francisco is a 42-story building with a cast-in-place concrete elevator core with 24" thick walls reinforced with BauGrid® WRG at four inches (4") on center the full height of the building. In this structure, one BauGrid® WRG replaces thirty-two (32) individual conventional hoops and cross-tie confinement reinforcement pieces.

The contractor, WEBCOR, with the help of the reinforcing sub-contractor, RPS of Tracy, CA, perfected a new construction system using BauGrid® WRG that reduced the construction cycle from one floor completed every seven (7) days to one floor completed every four (4) days on the 42-story project.

ONE FLOOR COMPLETED EACH THREE DAYS IN SAN FRANCISCO

RPS and BauGrid® WRG supplier BauTech®, Inc. are now planning for the construction of two buildings to be constructed this year in San Francisco, a 24-story and a 47-story structure both reinforced with BauGrid® WRG.

The owners will save about $1.5 million with the guarantee from RPS that a floor will be completed every three days.

SEVENTY-FIVE PERCENT (75%) LABOR SAVINGS

A 1.2 million s.f. project in Long Beach, CA, the site of the 1933 earthquake, was recently completed using rapid tunnel form construction. When the contractor, High Rise Construction, switched from conventional hoop and cross-tie reinforcement to BauGrid® WRG, it reduced the labor for the assembly of the reinforcing cages by more than seventy-five percent (75%).

Figure 5 - Long Beach Project Showed 75% Cage Assembly Labor Reduction

[1] Englekirk, Robert E., 2002, "Design –Construction of the Paramount – A 39-Story Precst Prestressed Concrete Apartment Building" *PCI Journal, Aug. 2002*

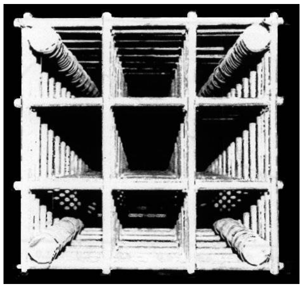

Figure 6 - Testing Shows Increased Strength Despite 17% Reduction in Confinement Steel Area

SUPERIOR INELASTIC DEFORMABILITY OF BAUGRID® WRG REINFORCED COLUMNS

In the tests of BauGrid® WRG reinforced columns at the Ottawa Carleton Earthquake Engineering Research Centre by Prof. Murat Saatcioglu[2], it was found that even with 17% less confinement cross-section area, the members showed 5 to 10% higher strength than conventionally reinforced columns. Prof. Saatcioglu attributes this superior performance of the BauGrid® WRG reinforced columns to "improved confinement of grids associated with increased rigidity of welded ties."

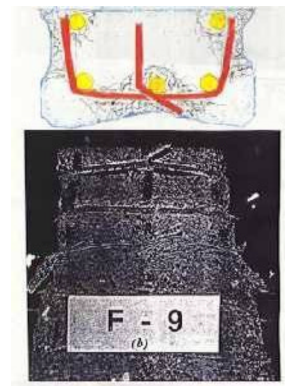

Figure 7 - Prof. Shamin Sheik Testing Shows Premature Failure

PREMATURE FAILURE OF CONVENTIONAL CROSS-TIES DUE TO SPALLING OF CONCRETE COVER

Tests were performed by Prof. Vitelmo V. Bertero[3] at the University of California, Berkeley, with the BauGrid® WRG reinforced boundary element specimens made as if all of the concrete cover had been lost due to spalling. These tests were in response to tests done by Prof. Shamin Sheik[4], who found in his test at the University of Toronto that conventional cross-ties failed prematurely due to concrete cover spalling.

SUPERIOR PERFORMANCE OF BAUGRID® WRG REINFORCED MEMBERS CAST WITHOUT CONCRETE COVER

The tests at UC Berkeley by Prof. Bertero showed that BauGrid WRG reinforced specimens without concrete cover performed in a superior manner to conventionally reinforced members with concrete cover.

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[2] Saatcioglu, M. and Grira, M., 1996, "Concrete Columns Confined with Welded Reinforcement Grids," *Ottawa Carleton Earthquake Engineering Research center - Report OCEERC 96-05, September.*

[3] Bertero, V., Miranda, E. and Thompson, C., 1990, "Cyclic Behavior of Shear Wall Boundary Elements Incorporating Prefabricated Welded Wire Hoops, *Earthquake Engineering Research Center, College of Engineering, University of California, Berkeley, January.*

[4] Sheikh, M. and Toklucu, M., 1993, "Reinforced Concrete Confined by Cylinder Spirals and Hoops", *ACI Structural Journal, September-October*

SPEED OF BAUGRID® WRG CAGE FABRICATION

Contractors such as RPS and others have found that automated assembly methods are possible when using BauGrid® WRG because of the very exact tolerances (±1/8") of the BauGrid® WRG. Significant reduction in the amount of labor used in cage fabrication is possible when using BauGrid® WRG as confinement reinforcement.

SPEED OF INSTALLTION OF BAUGRID® WRG CAGES

Figure 8 – Rapid Installation of BauGrid® WRG Cages Using SpliceGrids™

The speed at which BauGrid® WRG cages can be installed has been documented in the San Francisco projects and in a San Diego 24-story project where proprietary SpliceGrids™ were used to rapidly connect the vertical edges of the BauGrid® WRG cages.

Only four (4) vertical rebars are needed to complete the connection of the horizontal BauLadders®.

The welded intersections of the BauGrid® WRG allows the use of much taller cages because the BauGrid® WRG resist corkscrewing and deformation of the cages during installation.

RECENT BRIDGE DESIGN WITH BAUGRID® WRG REINFORCED HOLLOW TOWERS

The success of BauGrid® WRG in tall California earthquake resistant buildings has caused great interest in using BauGrid® WRG in hollow bridge towers. Structural engineers have found when designing tall buildings in seismic zones that the elevator cores are a very efficient earthquake resisting element when reinforced with BauGrid® WRG.

Similarly, bridge designers are presently evaluating the use of BauGrid® WRG reinforcement in hollow bridge towers.

BLAST RESISTANT PROPERTIES OF BAUGRID® WRG REINFORCED HOLLOW BRIDGE TOWERS

The superior energy absorbing properties of BauGrid® WRG reinforced members evidenced in test results for earthquake resistance, can be applied to designs of blast resistant buildings and bridges.

PROPRIETARY ENERGY DISSIPATING COUPLER

Figure 9 - BauCon Visco-elastic Coupler/Damper

Building and bridge designers have recently shown a great interest in a proprietary rebar coupler sold under the name of BauCon™ by BauTech®, Inc. The BauCon™ coupler is designed to act as both a rebar coupler and a visco-elastic damper. Tests are planned to verify its application in blast design.

CONCLUSION

The development of the BauGrid WRG technology has again shown how close communication between Researchers and Design and Construction Engineers results in significant advances in design and construction technology. The author wishes to recognize and thank the many Design and Construction Engineers and Civil Engineering Professors who have been an important part of the advancement of this new technology.