| July 2019 Research Seminar: Durable UHPC Columns with High-Strength Steel | | |
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| **#** | **Questions** | **Responses** |
| | **Availability Issues** | |
| 1 | Can you comment on the "Buy America" provision relating to steel fibers needed in UHPC? | To our knowledge, vendors are researching several fiber options to remain in compliance with the Buy America Act. |
| 2 | Please address the availability of high strength steel in the Midwest states. | We do not have a specific answer, but the mill that produced the HSS used in this study (in Oregon) seems to have sister mills in other states. |
| | **Cost** | |
| 3 | What is the cost of UHPC compared to common concrete, 35-45 Mpa (5000-6500 psi)? | A direct answer would be misleading, as the impact of material costs versus total project costs is what matters. |
| 4 | What is the increase in cost of a UHPC column relative to a conventional column? | No formal analysis was done to answer this question, but accounting for this cost as part of total project costs and long-term benefits would bring feasibility. |
| | **General** | |
| 5 | How prevalent is the use of precast concrete columns in bridge construction? | It is not widely used now because their connections to the footings are still under research, but some states have already started implementing precast concrete columns in bridges. |
| 6 | What is the future scope of UHPC columns for the construction industry? | It is very promising, especially in high rise buildings where the size of the columns is always an issue. |
| 7 | Please address any efforts underway with PCI or AASHTO relative to pretensioning or post-tensioning UHPC columns. | None that we are aware of yet. PCI and FHWA are currently focused on girders. |

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| 8 | Are there any additives available to protect the steel in the event the UHPC cracks? | The porosity of UHPC is minimal, and that's what makes UHPC a durable material. UHPC has very small crack widths at the design load and normal loading stage, and they start to be noticeable at very late stages of loading (around the failure of the whole column). |
| 9 | Can you comment on issues regarding the use of ecological concrete and its application in the field of structural engineering? | This is out of the scope of this study. |
| 10 | Could you discuss tests that you would like to conduct, but are lacking the funds and/or the facilities to conduct them? | Shake table tests for ultimate verification of dynamic behavior. |
| | **Questions during Seminar** | |
| 11 | The raw materials that make up UHPC are the main contributor to the increased price. Since UHPC requires such a high volume of raw materials, it is not an environmentally friendly substance. In order for UHPC to become a viable material for bridge and building construction, research must be done to find substitute materials that come at a cheaper cost and that are more environmentally friendly. Where can these cheaper materials be sourced from? | There is a lot of research addressing these interesting ideas (e.g., green concrete), but no one yet has started to look at making a green concrete with ultra-high strength like UHPC. |
| 12 | What were the compressive strengths of the NSC and UHPC you used? | NSC is 5 ksi, while the average strength of UHPC at test day was 30 ksi. |
| 13 | What were the residual displacements at the end of the tests? Were there any residual displacements observed in which the specimens were forced back to their original plumb position? | The specimens were forced back to their original plumb position by the horizontal actuator, but overall the UHPC columns exhibited less residual drifts than NSC columns. For more insights about the residual drift, please review our first publication out of this project (https://www.researchgate.net/publication/342697297_Comparative_Structural_Response_of_UHPC_and_Normal_Strength_Concrete_Columns_under_Combined_Axial_and_Lateral_Cyclic_Loading). |

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| 14 | Have you considered only the fibers and no hoop reinforcement? How would it perform? | No, we didn't, but some people evaluated the axial response of unreinforced UHPC columns; they had a brittle failure with much less ductility than the horizontally reinforced columns. |
| 15 | Have you done a cost comparison between the samples in terms of actual cost impact on a project made using NSC versus UHPC? | No, we have not. |
| 16 | How much would the lateral force be reduced when you only use 15 ksi compressive strength but the same tensile properties? | A section moment curvature analysis was done in our first publication out of this project (https://www.researchgate.net/publication/342697297_Comparative_Structural_Response_of_UHPC_and_Normal_Strength_Concrete_Columns_under_Combined_Axial_and_Lateral_Cyclic_Loading) to investigate the moment contribution of the steel and the concrete in tension and compression. It was found that the tensile properties of the UHPC had a greater effect on the section moment capacity than the compression. That said, we wouldn't expect much reduction in strength. |
| 17 | Given that failure is due to rebar rupture, from the repair point of view, what is the benefit of using UHPC and HS rebar? | Failure of columns, either UHPC or NSC, is always due to bar rupture or concrete spalling. However, the UHPC column is found to have much less damage than the NSC if subjected to the design loads or moderate seismic events. No concrete spalling nor rebars buckling, or even large cracks, were observed till 7% drift. |
| 18 | What is wrong with a 30% decrease in drift with much less Grade 100? Are you still getting enough drift? | The answer depends on desired design tagets and adopted philosophy, but techncially nothing wrong and drift capapicty is sufficient |
| 19 | Why are you waiting for someone to tell you the R value? Why don't you recommend values for UHPC? | That is what we are hoping to do in future research studies. |

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| 20 | If the failure mode is the tensile failure of the reinforcement, are there any warning signs of failure of the member prior to fracture, i.e., is it a catastrophic failure or will there be signs of overstress prior to collapse? | Only some concrete crushing and some cracks on the surface were observed before failure, but there still needs to be a way to evaluate the damage state of such columns after a seismic event. |
| 21 | Could you comment on the energy dissipation of UHPC specimens compared to normal strength concrete, for example, using the relative energy dissipation ratio (beta) per ACI 374.1-05? | We did not estimate that parameter. |
| 22 | What concrete cover was used on the reinforcement? Was it proportional to the member size? | The clear cover was 0.75 inch for all columns. |
| 23 | Can you comment on the early warning signs of failure for this type of column? | Only some concrete crushing and some cracks on the surface were observed before failure, but there still needs to be a way to evaluate the damage state of such columns after a seismic event. |
| 24 | What parameters were used to scale the column? I am a Ph.D. student at the University of Ottawa and am supposed to do a similar project. Are there any references in this regard? | This study is mainly a comparative study. However, a 1/5 scale was chosen of a typical California bridge column, and typical bridge reinforcements and axial load ratios were also chosen. |
| 25 | If we have a 25-30 ft long bridge column in real construction, why are you using UHPC in 80% of the column at mid height? | This is mainly to keep the axial load strength of the column and reduce the overall weight of the columns to be easier for transportation and handling for implementation in ABC applications. Additionally, this research is still preliminary for the seismic response of UHPC columns, and a further study needs to be done to investigate the most efficient way to combine both UHPC and NSC in columns. |

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| 26 | Understood that UHPC column has higher force (i.e., flexural) capacity (~80% higher) than a same size NSC column, and the draft capacity is about similar. For a same size UHPC column, with the same exact bridge, it will experience higher force demand than the NSC column due to its higher stiffness. Have studies been done to determine the increase in force demand? If so, what is the number? | Not yet. This is an interesting point that we are hoping to tackle in a future research study that looks into design aspects. |
| 27 | Is there any chance to share your OpenSees codes? | The OpenSees code has been shared. |
| 28 | The life of a bridge is far more affected by the superstructure deterioration than by the columns. | In bridges, the columns are always designed to undergo high inelastic deformations when subjected to seismic events. The UHPC columns have much damage state than the NSC columns and much less cracks which will eventually help extend the bridge life. |
| 29 | Was there a reason a hollow UHPC column was not considered? | This is a viable option, but due to test scale limitations we wanted to start with a solid column first. |
| 30 | Did you study the P-Delta effect while calculating the moment-displacement curve? | The way the columns were tested ensured that the axial load is always concentrically applied to the columns. |