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HSS

ARTICLE

PRACTICAL GUIDANCE FOR CONCRETE FILLED HSS COLUMNS

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Filling Hollow Structural Section (HSS) columns with concrete is a means to achieve increased compression capacity through composite action. There are other benefits to a concrete-filled HSS column including increased fire endurance (research has shown up to 3 hours depending on the level of loading), reduction in the requirements for costly coatings for fire protection, shielding of the concrete column inside the HSS during a blast event, and even increases in connection capacity in some configurations. While many engineers may be aware of these benefits, there are often questions about the practical aspects of making it happen. What kind of concrete should I specify? How does the concrete get in there? What are the pitfalls or limitations? We hope to answer these questions for you in this month's eNews article.

HSS columns can be filled with plain concrete, bar reinforced concrete, or even steel fiber reinforced concrete. There are some concrete design considerations that will vary for each job, and some of the most common are described below:

- Per AISC 360-10, Section I1.3(1), normal weight concrete compressive strength, f'_c, must be between 3 ksi and 10 ksi. Lightweight concrete compressive strength must be between 3ksi and 6 ksi.

- A standard concrete mix can be used for filling HSS columns provided there is little or no rebar required in the design. If a large amount of rebar is required, the mix may need to be revised to include smaller aggregate and higher slump. High strength grout can also be used to fill HSS columns in lieu of concrete.

- Per AISC 360-10, Section I1.3(2), the yield strength of bar reinforcement must be less than 75 ksi.

- Per AISC 360-10, Section I2.2a, the area of reinforcement within a concrete filled HSS composite column must be at least 1% of the total composite cross section area.

- If reinforcement inside the HSS column has been specified, the designer should carefully consider the constructability of the column assembly. Is there adequate space in the cavity of the HSS for both a concrete tremie and the reinforcement? Have the type of connections to the column been selected such that they won't interfere with the placement of the reinforcing? Through-plate type connections can make installation of the reinforcement and concrete complicated or even impossible.

- Is the top of the column a bearing condition (i.e. is load being transferred directly to the top of the column such as a beam bearing on a column cap plate)? If so, is the steel section capable of carrying all of the load? Is the design based on some of the load being delivered directly to the concrete inside the HSS? The designer must detail the top of column condition to ensure load is transferred to the column in a manner that is consistent with the design assumptions. Due to concrete shrinkage, a void can be expected to form between the top of concrete and underside of a column cap plate. To address this, the top 2-4 inches of the column can be filled with non-shrink grout (in which case fill and vent holes will be necessary). Alternately an embedded anchorage can be designed at the underside of the cap plate such as headed studs or anchor rods (similar to a base plate condition).

Placement of concrete in HSS columns is typically done after the column has been erected in the field. Concrete can be pumped through an opening in the top or bottom of the column using the same types of equipment that would be required for filling tall concrete wall forms. Alternatively, a staging area can be set up on site where the columns are filled in a vertical or inclined position. Employing this method means all columns could be filled at one time.

Regardless of method used, care must be taken by the concrete contractor to ensure that the concrete does not segregate during placement (per ACI 318-14, Section 26.5.2.1(f)). Additional information about concrete placement requirements and recommendations can be found in ACI 304R, chapter 5. The primary concern is to avoid any situation where concrete could free fall and hit the HSS walls, reinforcement, or other appurtenances present within the HSS cavity. Mixtures such as wet concrete tend to spread out the farther they free fall, so if concrete were placed by a pipe located at the top of an HSS column, and with a pipe diameter much smaller than the column, it would still be expected that at some distance into the column the mixture would begin hitting the HSS walls or reinforcement at which point segregation can occur. For this reason, a good rule of thumb is that concrete should not free fall more than 3 to 5 feet. In order to achieve this, concrete placed through an opening in the top of an HSS column should be done so by means of a tremie chute (aka elephant's trunk). In addition, the concrete may need to be vibrated to achieve adequate consolidation. Some contractors prefer to use a selfconsolidating concrete mix in lieu of more standard mixes to avoid the concrete vibration effort.

The designer should detail access for the tremie chute in the top of HSS column. This can be achieved simply if no cap plate is required. If a cap plate is required for bearing or top of column connections, specifying it to be field welded after concrete placement or detailing a hole to allow for concrete placement would be necessary. It may also be prudent to specify smaller holes (approximately 1" in diameter) in the column for venting and concrete fill verification. These holes will also become active in a fire scenario in order to vent any steam that is created inside the HSS due to the increased temperatures. Without these holes or other means of venting, tests have shown that the pressure due to the buildup of steam within the HSS can become high enough to deform or even rupture the HSS during a fire event.

Another option for placing the concrete within the HSS is to pump the concrete in lifts through openings spaced along the length of the column. This is very similar to how a tall wall form could be filled in lifts through holes in the side of the form. ACI 304R has additional information and direction on the correct way to perform this filling method. The holes required in the side of the column for this method are fairly large, so their impact on the column capacity must be evaluated by the designer. A vent hole at the top of the column should be designated if the column has a cap plate.

The contractor can locate the holes at floor level, in an office building for example, so that the concrete filling operation for the column can be coupled with concrete placement of slab on deck for each floor. In this way, the sequence of filling HSS columns after they have been erected can be aligned to what is generally considered a normal sequence of construction for most projects.

If the column is being filled for fire resistance, the method of loading the member should be given special attention. It is a common misconception that concrete-filled HSS columns are protected from fire by the heat sink effect of the concrete inside. This is not the case. The axial load that is required to be carried by the column during a fire event is actually shed from the steel outer shell to the concrete inside, which eventually carries this full axial load by itself. The designer should take this into account when detailing connecting members. More information pertaining to these considerations can be found in the paper titled "Design of Concrete-Filled Hollow Structural Steel Columns for Fire Endurance" by V. Kodur and D. MacKinnon (AISC Engineering Journal, v37, No. 1, January 2000, pp. 13-24).

Concrete filled HSS columns have numerous structural advantages and can provide aesthetically pleasing interior features. If care is taken by the designer to consider the constructability and construction sequence for these columns, construction of these columns will be easy to coordinate with the typical construction schedule and will provide value to the project overall.

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