Attachment H. North American Strand Producers (NASP) Test

There are various tests available for measuring bond between concrete and prestressing strands. The quality of bond is generally considered to be a primary influence on transfer and development lengths. The developers of the NASP test were trying to devise a test whose results were very repeatable. Prior to the NASP test, there was a large variation observed in the data collected from various pull out tests over the years. It was felt that there was a need to develop a standardized test for bond that would be repeatable at the same testing site, reproducible between sites and provide reliable prediction of the performance of a tested strand in a prestressed concrete product.

The NASP test was performed on all strand used to investigate transfer and development length in lightweight concrete in this research program. This Appendix describes the tests and presents the results for the 0.5 in. and 0.6 in. diameter strand used in this research.

Fundamental Explanation of NASP Test

In the NASP test, a single strand is cast into mortar contained within a steel pipe. The strand extends approximately 18 in. from one end of the pipe and about 1 in. at the opposite end. The mortar mix is controlled by strict flow and strength requirements and is cured for 24 hours at a prescribed temperature range. After curing, the specimen is placed in a testing machine and the long end of the strand is gripped. An LVDT is placed to measure movement of the short end of the strand. A tensile force is applied to the strand at a specified rate until the strand begins to slip within the mortar. The recorded NASP test value is the force at 0.1 in. slip that occurs at the free end as measured by the LVDT. The NASP test requires that a minimum of six specimens be tested for acceptance of the test results.

The test, which is also referred to as the Standard Test for Strand Bond (STSB), is currently being balloted for adoption as an ASTM standard test. The test will not set a threshold value for acceptance of the strand. This eventually will be determined and included as part of the ASTM standard for prestressing strands (ASTM A416). The threshold value that is currently considered by the authors of the test to indicate strand with acceptable bond for 0.5 in. diameter strand is 12,000 lbs for the average of six tests, with no individual test falling below 10,500 lbs. These values and those for 0.6 in. strand are presented in Table 1. The values for 0.6 in. strand are 1.2 times the values for 0.5 in. strand, which is the ratio of their diameters.

Table 1 Proposed NASP Test acceptance threshold values

Strand type	Average of six tests, lbs	Lowest allowed single test, lbs
0.5 in. regular Grade 270 prestressing strands	12,000	10,500
0.6 in. regular Grade 270 prestressing strands	14,400	12,600

Mortar Consistency

The NASP test was developed to characterize bond quality and eliminate concrete quality as a variable from the bond quality. Therefore, to ensure consistency of the mortar properties, the NASP test has a strict flow and strength requirements for the mortar which fills the pipe. These parameters dictate the quantity of sand, cement and water used in the mixture. The test mix remains the same irrespective of the actual concrete mix that will be used with the prestressing strand in any given project.

NASP Test Specimen Setup

A NASP test specimen (see Figure 1) is made of an 18 in. long steel pipe, 5 in. in diameter and 0.375 in. in thickness. A 1/4 in. thick steel plate, 6 in. wide and 6 in. long is welded to the bottom end of the steel pipe. A 9/16 in. hole is made in the plate for a 0.5 in. strand and an 11/16 in. diameter hole is made for 0.6 in. prestressing strand. A pair of angles at least 2 in. wide is welded to the other end of the steel pipe to which the LVDT is mounted. The length of the strand is 45 in. and it passed through the steel pipe and the plate. Approximately 2 in. of strand protrudes above the steel pipe (opposite end from the welded steel plate) with 2 in. bond breaker inside the steel pipe at the welded plate end. Thus, the bonded length inside the steel pipe is 16 in. with 2 in. unbonded length at the bottom of the specimen.

Figure 1. NASP Test Specimen

NASP Test Design Mix

The NASP test protocol requires the mix to have a particular flow and strength. The Ramirez and Russell (2007) recommendation was followed while preparing the grout mix. The mortar mix prepared was required to have a flow of 100 to 125 percent on a standard flow table, and a compressive strength of 4500 to 5000 psi at 24 hours. For the research program, 30 iterations were required to obtain an acceptable mix. Three specimens were prepared from each batch of mixture. The details of the sand and cement proportions along with the water are presented in Tables 2 and 3 for 0.5 in. strand and 0.6 in. respectively. The absorption rate of sand was found to be 2.2 percent using the Standard Test Method for Specific Gravity and Absorption Rate of Fine Aggregate (ASTM C 128-97). It should be noted that these trials were carried out on small batch of sand as compared to the actual mix used for the test. The trial typically consisted of about 2.5 lb of sand, 1.5 lb of cement and roughly 0.6 lb of water. Additional water was needed during the preparation of grout to satisfy the flow requirements. Additional water was added in portions of 0.2 lb by checking the flow each time.

Table 2. Mixture used for 0.5 in. Strand Specimens

Sand (lb)	60
Cement (lb)	34.5
Water (lb)	16.2
Additional water (lb)	2.3

Table 3. Mixture used for 0.6 in. Strand Specimens

Sand (lb)	60
Cement (lb)	35
Water (lb)	16.5
Additional water (lb)	0.8

NASP Test Specimen Fabrication

The strands to be tested were cut to a length of 45 in. each. A 2 in. bond breaker was attached to the strand such that the bond breaker was applied 18 in. from one of the ends as explained previously. A piece of duct tape was used as a bond breaker. The strand was passed through the steel pipe and the 1/4 in. thick plate welded to its bottom face such that the bond breaker was at the bottom of the steel pipe but above the steel plate. The strand projected approximately 2 in. from the top of the steel pipe. Precautions were taken during pouring of the grout so that the strand was vertical. Figure 1 is a photo of the completed specimen and Figure 2 is a photo of the empty “can”.

Figure 2. NASP specimen before filling (welded plate, angles are visible)

The grout was mixed in a two cubic foot mixer. The mixer was sprayed with water first to make it wet for use. The oven dried sand was placed in to the mixer while the blades within the mixer were turning. Half the water that was to be used was added to the mixer with the blades turning to moisten the sand. Then entire quantity of cement to be used was added to the sand in the mixer. With the blades turning, the remaining water was added to the mixer. The grout was allowed to mix for 3 minutes. The blades were stopped and the grout was scraped off the blades and the sides and the grout was mixed manually in the mixer using a scoop. The grout was allowed to mix for 3 minutes again. The flow test was carried out to check the flow before placing the mix inside the steel pipes. Additional water was added if required as explained earlier to adjust the flow. This mortar mix was placed in to the specimens in three layers each. Care was taken to ensure that the strands remained vertical. The samples were mounted in a frame and kept in the moist curing room at a temperature of 70 F and allowed to cure overnight.

NASP Test Setup

The NASP test specimens were tested in the Satec universal testing machine. The NASP test protocol suggests that the strand be tensioned (gripped for applying tensile force) approximately 6 in. from the bottom of the strand. In this regard, the frame used by Loflin (2008) was used for the test. The frame can resist load of about 65 kips which is the breaking tensile strength of a 0.6 in. diameter regular prestressing strand. The frame is approximately 3 ft high and made of steel plates (see Figure 3). The strand passes through the 11/16 in. hole located on the top plate. A prestressing chuck is used to hold the strand in the position and apply the tension. A spacer, 4 in. long is also inserted between the bottom of the top plate and the prestressing chuck. This aids in the removal of the sample from the Satec after the test is completed. The prestressing chuck bears against the spacer and spacer bears on the bottom of the top plate.

Figure 3. Steel frame used for loading

An MTS 407 controller was used to control the tensile force that was applied to the specimen. A Linear Variable Displacement Transformer (LVDT) was used to measure the dead end slip which is the slip at the end of the strand which was not attached to the prestressing chuck. A System 5000 data acquisition system was used to record the readings and then reduce the data to excel spreadsheets. The StrainSmart system software recorded the applied load, crosshead displacement and the dead end slip through the LVDT. The NASP protocol requires that the test be carried out at a rate of 0.1 in/min. It also requires that the load rate shall not exceed 8000 lb/min. The test was load rate controlled as suggested by NCHRP Report 621 and the load rate was 7500 lb/min. The test setup is shown in the Figure 4.

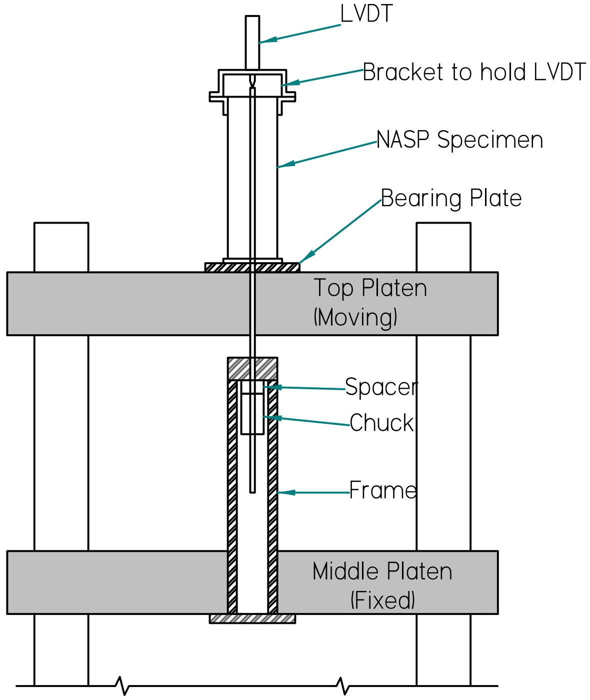

Figure 4. Schematic of NASP Test Setup

NASP Test Procedure

The specimens were moist cured for 24 hours. The specimens were inspected for radial cracking on the surface. This was done in accordance with NASP test protocol which suggests that the specimens cannot be tested if radial cracks are observed. The free end of the strand, that is the end from which the LVDT was to be suspended, was leveled and smoothed using a circular grinder. The overhead crane was used to position the specimen on top of the top crossframe of the Satec. The strand was passed through a 1 in. thick plate placed on the top platen to avoid damage to the platen. The strand also passed through the platen. The height of the small frame was adjusted using a 4 in. actuator so that the chuck can be positioned approximately 6 in. from the end of the strand (see Figure 4). The spacer was inserted accordingly. The central crosshead was adjusted such that the top of the bottom plate of the frame was flush with the bottom of the middle platen. A small bracket was used to suspend the LVDT from the free end of the strand. The frame was made of 1/4 in. thick plates and a nut was welded at the top of the frame to thread in the LVDT. The LVDT rested on to this frame. The frame is shown in Figure 4. The LVDT was threaded in such that the plunger would be close to the calibrated 0 in. reading.

The load cell was zeroed and the actuator was removed. At this point the frame was supported by the strand (through the chuck) so the load of the frame was applied to the strand. Some amount of tension was also applied to the strand (about 500 lbs). The crosshead displacement and the LVDT were zeroed. The system was armed and the loading was done at 7500 lb/min till the dead end slip was around 1.5 in. or the strand could not be loaded further or load had been increased beyond the NASP threshold value. After the test, the prestressing chuck was removed. This required the frame to be suspended over the actuator and the spacer was also removed. The specimen was checked for mortar cracking. The crane was used to remove the specimen from the test apparatus. The collected data was reduced to excel spreadsheets.

NASP Test Nomenclature

The test was carried out for two types of strands (0.5 in. and 0.6 in., regular grade 270) from only one manufacturer, MMI. The specimen nomenclature was as follows:

N.MMI.5R#4

N denotes NASP test. MMI is for manufacturer of the strands, .5 is the strand diameter, R is for regular strand (in previous research 0.5 in. special strands were also tested), and #4 is the repetition designation.

NASP Test Results

Two types of strands were tested using the NASP test. Six specimens were tested for each 0.5 in. and 0.6 in. regular grade 270 prestressing strands from MMI. Data for one specimen of each strand type was lost due to error during scanning of data using the MTS controller. The precision was set to zero for decimal places and hence the displacement recorded was zero. One specimen of 0.5 in. strand was lost during the process of initial set up of the test and loading using the steel frame.

The strands were loaded till they could not be loaded further. It was observed that the slip of the strands never exceed the 1.5 in. or the maximum calibration of the LVDT. Each test was stopped when the load could not be increased with increasing slip or crosshead movement.

NASP Mortar Mix

As mentioned earlier, there were complications with the preparation of grout mix. The standard practice of finding the compressive strength of the grout mix is by testing 2 in. by 2 in. grout cubes. The time frame available for testing is small and hence the cubes were tested in the middle of the NASP test. Hence, it is possible that the grout mix had gained more strength resulting in higher NASP bond values.

NASP Test Results

Tables 4 and 5 show the NASP test loads. As mentioned in earlier, the tests were stopped when the strand could not be loaded further, slip was occurring at the chucked end, or the slip recorded by dead end (LVDT) exceeded 0.1 in. The NASP bond value was to be considered as the load at 0.1 in. displacement of LVDT. If the LVDT displacement was less than 0.1 in. at the end of the test, then the value of load recorded at the end of the test was considered as the NASP bond value for the specimen tested.

Table 4. NASP test results for 0.5 in. strands

Specimen	Load at 0.1 in. slip, lbs	Maximum Load, lbs	Load required by NASP, lbs
N.MMI.5R#1	13000	13000	10500
N.MMI.5R#2	NA	12090	10500
N.MMI.5R#3	14700	14700	10500
N.MMI.5R#4	NA	20500	10500
AVERAGE	13850	15070	12000

Table 5. NASP test results for 0.6 in. strands

Specimen	Load at 0.1 in. slip, lbs	Maximum Load, lbs	Load required by NASP, lbs
N.MMI.6R#1	NA	16700	12600
N.MMI.6R#2	NA	10000	12600
N.MMI.6R#3	NA	17800	12600
N.MMI.6R#4	NA	18900	12600
AVERAGE	NA	15800	14400

The specimen N.MMI.6R#2 did not fail before the threshold value but the test was stopped as it appeared that the LVDT plunger had gotten stuck. It was not reloaded, but most likely would have surpassed the threshold value. The tests of the other specimens were stopped when the loads were well beyond the threshold value, and the slips were still less than 0.05 in.

The average results were at least 10% higher than the required NASP value. Although, due to testing problems, the required six test repetitions were not performed, the strands that were tested were above the proposed NASP threshold acceptance value. Therefore it was concluded that the strand bond quality was acceptable.