CENTRAL MIX TYPE MIXER TIME STUDY

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Michigan State Highway Department
John C. Mackie, Commissioner
Lansing, March 1961

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The purpose of this study was to gain knowledge of the effectiveness of mixing concrete in an 84S central mixer at variable mixing times with regard to uniformity of weight, air content, and slump of concrete; proportion of coarse aggregate to total aggregate; and comparative strength of the first and last parts of the batch.

Project Fb 11021, C8R and C9U, at Three Oaks, Michigan, with Eisenhour Construction Company as contractor, was selected for study. The mixer used was a Rex 84S tilt type set up as a central mixer mounted for easy portability. Materials bins also were of Rex manufacture.

The aggregate bin had two compartments charged by crane and clam bucket, with weigh hoppers slung beneath discharging on a belt conveyor. The scales were dial type and weighing procedures were controlled by pushbutton. The materials were discharged so as to maintain a ribbon flow of fine and coarse aggregate together on the belt.

The cement bin was charged by screw conveyor which fed either the storage bin from hauling trucks or the weigh hopper. The weigh hopper discharged by gravity flow directly to the mixer. A dial-type scale measured the weight of cement, this weighing mechanism being integrated into the same pushbutton control panel as the aggregates.

Figs. 1, 2, and 3 show the general plant setup. The scale control house is the small building beside the aggregate bins. The dial scale for the aggregate bin was just outside and visible from the scale house, and the cement dial scale was near the mixer and also plainly visible from the scale house. Water was metered to the mixer and also was controlled from the scale house.

Concrete was hauled in tilt-type wet batch trucks equipped with a rotating mechanism to agitate the mixture or discharge the batch.

For selecting portions of the batch, two 50-gal drums were cut down and equipped with bales, for batch hoppers. They were numbered for

Figure 1. Mixer, cement bin, traveling crane, and water tank.

Figure 2. Mixer, traveling crane, belt conveyor, aggregate bin, and control house.

Figure 3. Manipulation of testing batch hopper, tilted mixer, and cement dial scale.

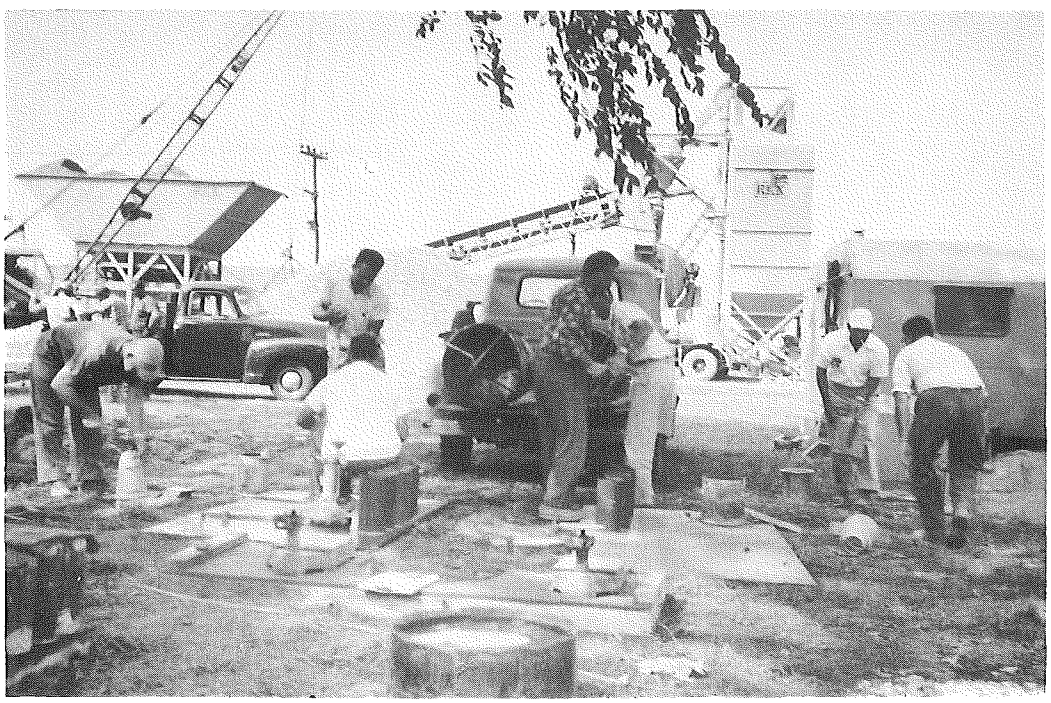

Figure 4. Testing site with batch plant in background.

identification and one was used for the first tenth and the other for the last tenth of the same batch. The hoppers were manipulated on two lines of a traveling crane as shown in Fig. 1.

After the portions were selected, they were lowered to a pick-up truck and transported about 200 ft to the testing site (Fig. 4). Here they were tipped on their sides and samples taken as needed for the various tests.

TEST PROCEDURE

General Procedure

Three rounds of cycles each were conducted for mixing times of 2-, 1-1/2-, 1-, and 3/4-min. For information of the contractor's superintendent, a partial cycle was performed at 1/2-min with part of the tests made at the mixer and the remainder on the same batch deposited at the paving site.

Detailed Test Procedure

The charging time started with the first material to enter the mixer and terminated when the complete batch was contained. The mixing time began at the end of the charging time, as near as could be determined, and stopped after the required period.

Mixing being completed, the mixer was stopped and the first hopper swung to position in the batch truck. The mixer was tilted until the hopper was filled and then returned to an upright position. After the first hopper was removed, the mixer was again tilted until 80 to 90 percent of the batch was discharged. Then the second hopper was swung into position and the remaining concrete in the mixer was emptied. Occasionally the drum had to be rotated slightly to complete the discharge.

As soon as the hoppers were hauled to the testing site, as previously described, tests were performed. One group of workers proceeded to test from the first hopper, the other the second. There was no additional mixing of the concrete once it left the mixer.

First, slump, air content, and weight pcf tests were conducted simultaneously. Test cylinders were molded and washout tests performed immediately afterward. Two 4- by 8-ft by 3/4-in. plywood work platforms were provided to keep the two portions of the batch separated. A pressure water supply, storage platform, and curing burlap were furnished by the contractor.

Six test cylinders were cast from each portion of each batch, stored on the storage platform, numbered, and covered with wet burlap.

For separation of coarse aggregate from the batch, the material used in the slump test was weighed and washed over a No. 4 sieve. The washed coarse aggregate samples were put aside in individual clean labeled sample sacks until several cycles were completed, and then surface dried, weighed, and the percentage determined.

A portion of the test cylinders cast on Wednesday were field cured until Friday before being transported to the Ann Arbor Laboratory. The rest were kept wet and taken to the laboratory the following Monday where all specimens were placed in the moist room for the remaining curing period.

SUMMARY OF TEST RESULTS

Table 1 contains the complete test data. Each batch was given a cycle number and each series of test cylinders was given a letter code for easy identification. This table also contains mix proportions as corrected for moisture content for the several cycles.

Table 2 is an extraction of data from Table 1 for easier comparison of the first and last portions of the same batch. Concrete proportions are omitted from Table 2.

TIMING

Cycle 4 was the first to be conducted after the mixer was operating in the 1-1/2-min range for normal paving operations. The purpose was to start with as few changes as possible to get the proper perspective of the plant operation without confusing the plant operators. The mixing time was somewhat shorter than that planned in the early test due to partial dependence on the automatic timer. This timer was activated with the tripping of the aggregate batch hoppers, and a standard 15-sec charging time was assumed and added to the mixing time setting. Often the cement weigh hopper did not completely empty and as a result the true mixing time was not obtained. In this case there was an overlap of charging and mixing time periods. The amount of cement held back was about 4 to 8 lb, resulting in an overlap of as much as 8 to 10 sec. The automatic timer was not relied upon after the first few batches and the timing was measured by stop watches.

TABLE 1
MIXER TIME STUDY

Date Cast	Cycle No.	Portion of Batch	Charging Time, Sec.	Mixing Time, Sec.	AE Agent Per Sack, oz.	Air Content %	Weight per Cubic Foot, lbs	Slump, in.	Concrete Temperature, F	Coarse Agg. in Sample, %	Test Speciman Series Identification	7 Day Strength, psi				28 Day Strength, psi			
												1	2	3	Average	1	2	3	Average
Sept. 7, '60	1	first tenth	15.0	115	0	6.4	140.4	4	85	40.0	A	2760	2440	2740	2650	3430	3360	3570	3450
Sept. 7	2	first tenth	19.0	120	0	6.2	140.4	4 3/8	86	40.7	C	2790	2580	2860	2740	3180	3450	3640	3420
Sept. 7	3	first tenth	21.0	120	0	6.5	138.9	2 3/4	86	45.0	E	2760	2530	2610	2630	3360	3180	3460	3330
Average						6.4	139.9	3 3/4		41.9					2673				3400
Sept. 7	1	last tenth	15.0	115	0	6.4	142.0	2 3/4	85	47.8	B	2540	2530	2860	2680	3410	3600	3390	3470
Sept. 7	2	last tenth	19.0	120	0	6.1	142.5	3	86	43.0	D	2400	2700	2650	2580	3320	3430	3570	3440
Sept. 7	3	last tenth	21.0	120	0	6.0	141.5	3 1/4	86	43.8	F	2400	2530	2280	2400	3300	3390	3570	3420
Average						6.2	142.0	3		44.9					2553				3443
Sept. 7	4	first tenth	29.5	80	3/8	7.3	139.9	2 3/4	84	42.5	G	2700	2460	2630	2600	3230	3290	3410	3310
Sept. 7	5	first tenth	20.0	88	0	6.0	144.0	3 1/2	87	41.7	I	3000	3110	2830	2980	3980	3750	3850	3860
Sept. 7	6	first tenth	21.0	86	0	5.8	141.9	5	85	47.5	K	2720	2920	2530	2720	3600	3410	3710	3570
Average						6.4	141.9	3 3/4		43.9					2767				3580
Sept. 7	4	last tenth	29.5	80	3/8	8.1	138.5	2	84	43.0	H	2690	2600	2510	2600	3460	3390	3450	3430
Sept. 7	5	last tenth	20.0	88	0	5.8	144.8	1 1/4	87	42.1	J	2790	3060	2770	2870	3640	4030	3890	3850
Sept. 7	6	last tenth	21.0	86	0	5.5	144.5	2	85	50.0	L	2790	2690	2560	2680	3390	3290	3460	3380
Average						6.5	142.6	1 3/4		45.0					2717				3553
Sept. 7	7	first tenth	----	60	0	5.3	140.4	4 1/4	87	43.0	M	2690	2630	2530	2620	3890	3450	3710	3680
Sept. 7	8	first tenth	25.0	60	0	4.3	142.4	3 1/2	85	46.7	O	2900	2770	3000	2890	3750	4130	3850	3910
Sept. 8	9	first tenth	22.0	60	0	4.4	143.3	2 1/4	83	42.6	Q	2470	2900	3060	2810	3960	3820	4060	3950
Average						4.7	142.0	3 3/8		44.1					2773				3847
Sept. 7	7	last tenth	----	60	0	5.4	144.5	2 1/4	87	44.7	N	2690	2300	2420	2470	3300	3430	3640	3460
Sept. 7	8	last tenth	25.0	60	0	4.5	145.5	1 1/2	85	45.7	P	2560	2600	2690	2620	3600	3990	3820	3800
Sept. 8	9	last tenth	22.0	60	0	4.3	143.0	1 1/2	82	43.9	R	2860	2790	2700	2780	3460	3710	2530	3570
Average						4.7	144.3	1 3/4		44.8					2623				3610
Sept. 8	10	first tenth	28.0	45	3/8	3.6	142.8	3 1/2	83	41.0	S	2760	2970	3060	2930	4030	3830	4200	4020
Sept. 8	11	first tenth	22.0	45	5/8	4.1	142.8	5 3/4	83	45.5	U	2440	2610	2420	2490	3220	3300	3390	3300
Sept. 8	12	first tenth	20.0	45	1	6.1	142.4	4	82	44.1	W	2690	2580	2700	2660	3460	3600	3410	3490
Average						4.6	142.7	4 3/8		43.5					2693				3603
Sept. 8	10	last tenth	28.0	45	3/8	3.8	144.5	2 1/2	83	45.2	T	2920	2790	2990	2900	3710	4060	3960	3910
Sept. 8	11	last tenth	22.0	45	5/8	5.3	142.0	2	83	41.4	V	2690	2300	2440	2480	3320	3270	3390	3330
Sept. 8	12	last tenth	20.0	45	1	5.9	141.0	2 3/8	82	42.0	X	2560	2400	2530	2500	3670	3230	3600	3500
Average						5.0	142.5	2 1/4		42.9					2627				3580
Sept. 8	13	first tenth***	25.0	30		3.0	-----	5 1/2	84	44.6	Y*	3130				3890			
Sept. 8	14	last tenth+	25.0	30		-	-----	2 3/8	84	44.0	Z*	2610				4060			
Sept. 8	15							1	--	41.8	YY**	3040				4280			
Sept. 8	16							1/2	--	43.2	ZZ**	2740				3780			
Average										43.4									

Note: Cycles 13 through 16 were made at Superintendent's request.
* Batch at plant
** Same batch deposited on grade
*** First portion deposited on grade
\+ Last portion deposited on grade

CONCRETE PROPORTIONS

Material Sources and Basic Mix		Computed Batch per Cubic Yard		
		Cycle A thru F & M thru P	Cycle G thru L	Cycle Q thru X & Y, Z, YY, & ZZ
Cement: Huron, St. Joseph, Type 1A	94.0 lbs	470.0	470.0	470.0
Fine Agg: Rieth-Riley, Davis Pit (Abs. 1.31%)	278.8 lbs	1452.5	1440.0	1460.0
Coarse Agg: Monon Crushed Stone Co. (Abs. 0.76%)	367.7 lbs	1856.9	1842.2	1877.0
Water:	54.0 lbs	193.1	220.3	165.9
	Moisture: FA	4.2	3.3	4.7
	% CA	1.0	0.2	2.1

TABLE 2
MIXER TIME STUDY

Date Cast 1960	Cycle No.	Portion of Batch	Charging Time, Sec.	Mixing Time, Sec.	AE Agent Per Sack, oz.	Air Content, %	Weight per Cubic Foot, lbs	Slump in.	Concrete Temperature F	Coarse Agg. in Sample, %	Test Speciman Series Identification	7 Day Strength, psi				28 Day Strength, psi			
												1	2	3	Average	1	2	3	Average
Sept. 7	1	first tenth	15.0	115	0	6.4	140.4	4	85	40.0	A	2760	2440	2740	2650	3430	3360	3570	3450
Sept. 7	1	last tenth	15.0	115	0	6.4	142.0	2 3/4	85	47.8	B	2540	2630	2860	2680	3410	3600	3390	3470
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Sept. 7	4	first tenth	29.5	80	3/8	7.3	139.9	2 3/4	84	42.5	G	2700	2460	2630	2600	3230	3290	3410	3310
Sept. 7	4	last tenth	29.5	80	3/8	8.1	138.5	2	84	43.0	H	2690	2600	2510	2600	3460	3390	3450	3430
Sept. 7	5	first tenth	20.0	88	0	6.0	144.0	3 1/2	87	41.7	I	3000	3110	2830	2980	3980	3750	3850	3860
Sept. 7	5	last tenth	20.0	88	0	5.8	144.8	1 1/4	87	42.1	J	2790	3060	2770	2870	3640	4030	3890	3850
Sept. 7	6	first tenth	21.0	86	0	5.8	141.9	5	85	47.5	K	2720	2920	2530	2720	3600	3410	3710	3570
Sept. 7	6	last tenth	21.0	86	0	5.5	144.5	2	85	50.0	L	2790	2690	2560	2680	3390	3290	3460	3380
Sept. 7	7	first tenth	----	60	0	5.3	140.4	4 1/4	87	43.0	M	2690	2630	2530	2620	3890	3450	3710	3680
Sept. 7	7	last tenth	----	60	0	5.4	144.5	2 1/4	87	44.7	N	2690	2300	2420	2470	3300	3430	3640	3460
Sept. 7	8	first tenth	25.0	60	0	4.3	142.4	3 1/2	85	46.7	O	2900	2770	3000	2890	3750	4130	3850	3910
Sept. 7	8	last tenth	25.0	60	0	4.5	145.5	1 1/2	85	45.7	P	2560	2600	2690	2620	3600	3990	3820	3800
Sept. 8	9	first tenth	22.0	60	0	4.4	143.3	2 1/4	83	42.6	Q	2470	2900	3060	2810	3960	3820	4060	3950
Sept. 8	9	last tenth	22.0	60	0	4.3	143.0	1 1/2	82	43.9	R	2860	2790	2700	2780	3460	3710	3530	3570
Sept. 8	10	first tenth	28.0	45	3/8	3.6	142.8	3 1/2	83	41.0	S	2760	2970	3060	2930	4030	3830	4200	4020
Sept. 8	10	last tenth	28.0	45	3/8	3.8	144.5	2 1/2	83	45.2	T	2920	2730	2990	2900	3710	4060	3960	3910
Sept. 8	11	first tenth	22.0	45	5/8	4.1	142.8	5 3/4	83	45.5	U	2440	2610	2420	2490	3220	3300	3390	3300
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Sept. 8	12	first tenth	20.0	45	1	6.1	142.4	4	82	44.1	W	2690	2580	2700	2660	3460	3600	3410	3490
Sept. 8	12	last tenth	20.0	45	1	5.9	141.0	2 3/8	82	42.0	X	2560	2400	2530	2500	3670	3230	3600	3500
Sept. 8	13	first tenth***	25.0	30		3.0	------	5 1/2	84	44.6	Y*	3130				3890			
Sept. 8	14	last tenth+	25.0	30		-	------	2 3/8	84	44.0	Z*	2610				4060			
Sept. 8	15							1	--	41.8	YY**	3040				4280			
Sept. 8	16							1/2	--	43.2	ZZ**	2740				3780			

Note: Cycles 13 through 16 were made at Superintendent's request.
* Batch at plant
** Same batch deposited on grade
*** First portion deposited on grade
\+ Last portion deposited on grade

UNIT WEIGHT

In general the unit weight of concrete varied inversely with the air content of concrete, as would be expected. The range of weight pcf of concrete was from 138.5 to 145.5 lb; however, the maximum difference between the first and last tenths of a batch as an average of 3 cycles was 2.3 lb for the 1-min mix and the least difference was 0.2 lb for the 3/4-min mix. The difference for the 2-min mix was 2.1 lb and for the 1-1/2-min mix, 0.7 lb. Individual low unit weight of concrete was usually obtained where the air content was above the specification limit.

In no single instance was the weight of concrete sufficient to provide correct yield for the mix. The yield for all mixes was excessive.

AIR CONTENT

The first tests showed the air content to be slightly high due to excessive additive. The longer mixing time periods produced sufficient air without additive while the shorter periods required from 3/8 to 1 oz of additive. In the 3/4-min mix, the increment of additive began at 3/8 oz per sack of cement, which produced insufficient air content. With 5/8 oz the air content was below the average required, while 1 oz of additive produced an average of 6.0 percent of air. Had a constant amount of additive been maintained, the air content might have been too high in the 2- and 1-1/2-min mixes and too low on the short mixing time mixes.

SLUMP

The slump of concrete was higher in the first tenth of the batch than in the last tenth, with the single exception of test cycle 3. An explanation for this was offered by the superintendent who said the water discharge was timed so that part preceeded the aggregate and cement, and too much may have been pushed toward the discharge where it tended to keep that portion at a higher slump. The one exception cannot be explained. He suggested that in future work the charging of aggregate and cement be advanced with respect to the charging of the water to correct the situation.

In general, a fairly high slump was carried at the mixer because of the high air temperature and rapid drying of the mixture before it reached the road site. On both days of these tests, temperatures ranged to 100 F, causing the concrete to hydrate rapidly. This is indicated in cycles 13 through 16 where the slump at the mixer was from 2-3/8 to 5-1/2 in. while at the paving site, the slump from the same load ranged from 1/2 to 1 in.

Part of the variation in slump may have been caused by moisture variation in the stockpiled aggregate. The piles were low, requiring constant replanishing. The 6A aggregate was hauled directly from railroad hopper cars spotted nearby and was quite dry. Sand was hauled directly from the gravel pit and was very moist. This routine may have contributed somewhat to varying amounts of moisture carried by the aggregates.

PERCENT OF COARSE AGGREGATE IN SAMPLE

Only four individual tests showed percentages of 46.6 or more: cycle 1, last tenth; cycle 6, first tenth; cycle 6, last tenth; and cycle 8, first tenth. These represent mixing times of 2-min for cycle 1, 1-1/2-min for cycle 6, and 1-min for cycle 8. The average of all tests by mixing time was 43.4 percent for 2-min, 44.5 percent for both 1- and 1-1/2-min, 43.2 percent for 3/4-min, and 43.4 percent for 1/2-min.

The basic concrete proportions shown in Table 1 give quantities of fine and coarse aggregates in oven dry weights. If given in a saturated, surface-dry condition, they would read: cement, 94.0 lb; fine aggregate, 285.5 lb; coarse aggregate, 370.5 lb; and water, 47.5 lb. Since the percent of coarse aggregate as determined from field tests is shown as percentage of saturated, surface-dry coarse aggregate to total batch weight, the designed ratio should be 46.6 percent.

With the exception of the 3/4- and 1/2-min mixes at the plant, the last tenth of the batch contained a higher percentage of coarse aggregate than the first tenth. This generally may be related to slump, in that the higher slump concrete may have segregated slightly more than the lower slump concrete while being transported to the test site. This does not explain the difference in the 3/4- and 1/2-min mixes; however, the difference in percentage in both was only 0.6.

STRENGTH

In strength, no significant difference appeared between the first and last tenths of the mix. In the 2-min mix, the last tenth produced 43 lb more 28-day strength than the first tenth. In the 1-1/2-min mix, the first tenth produced 27 lb, the 1-min mix 237 lb, and the 3/4-min mix 23 lb more than the last tenth.

The lowest spread between individual low and high strengths occurred in the last tenth of the 2-min mix, where high was 3600 psi and low was 3300 psi. The spread for the first tenth was 460 psi. The greatest spread was found in the first tenth of the 3/4-min mix where the individual high was 4200 psi and the low was 3220 psi, with the difference of 980 psi. The last tenth was 4060 psi for high and 3230 psi for low for a difference of 830 psi.

In the same order, for the 1-1/2-min mix the first tenth was 3980 psi and 3230 psi; the last tenth was 4030 psi and 3290 psi. For the 1-min mix the first tenth was 4130 psi and 3450 psi; last tenth was 3990 psi and 3300 psi.

Only one cylinder was broken for each of the first and last tenths of the 1/2-min mix, except for two cylinders cast at the paving site. These two could not be classified by portion of the batch, but only as deposited concrete.

All 28-day strengths were above the minimum specification requirement of 3000 psi.

CONCLUSIONS

The timing of charging and mixing required careful observation of material movements. To insure that all materials were in the drum, the automatic timer preset for an average period of charging quite often would be in error. Also, any holdup of aggregate in the bin or lack of free flow would tend to throw mixing time off. For successful timing of the mixes, a stop watch was necessary.

There was a variation of 7 lb in weight pcf of concrete between the heaviest and lightest individual batches and all tests fell below the theoretical expected weight. If the air content could have been kept more constant, more uniform weight would probably have resulted. The least differences in average weight per time interval between the first and last tenths of the batch occurred in the 45-sec mix at 1-1/2-, 2-, and 1-min, in that order.

To keep air content within the specification it was necessary to adjust the additive with the different mix times. In two batches the air content was too high and in two batches too low. If several batches had been neglected and air tests made before selecting test batches, more uniform results probably would have been obtained in the 3/4- and 1-1/2-min mixes.

Concrete slump generally was higher in the first tenth of the batch than the last tenth when too much water preceded the aggregates and cement in the charging cycle. Variations in slump may have been due in part to hauling of fresh aggregate and rapid air drying of stockpiles. The air temperature was close to 100 F throughout the tests and had considerable influence on slump.

The percentage of coarse aggregate to total batch weight, with four exceptions, was less than the theoretical designed proportion. These low percentages may have resulted from problems in extracting slump samples for washing over the No. 4 sieve. In striking off concrete from the top of the cone, protruding pebbles often may be removed, whereas theoretically they should be included in the cone.

The strength tests did not indicate any great fluctuation related to any single factor of mix time, air content, or slump of concrete. However, the study was so limited in extent that conclusions cannot be justified on the basis of the data submitted.