THE DYNA FRAME SYSTEM OF STRUCTURAL BUILDING ELEMENTS

A completely pre-planned, pre-engineered structural system simplifies design for various building types and organizes plant production into a systematized industrialized method keyed to design. It utilizes precast, prestressed columns and beams with highly efficient standard connection details, and available standard cored-slab floor and roof units.

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Dyna Frame is a patented structural system that makes use of individual structural members which are field assembled to make the structural whole. Precast concrete beams and columns are used in conjunction with any of the standard cored-slab systems to comprise a structural frame in the conventional sense. The design of the members generally follows the ACI Building Code (ACI 318-63).

Dyna Frame is in current production in the Baltimore-Washington area, and has been used in a variety of building projects over the past three years, including multi-story motels, office buildings, parking garages, warehouses and schools. It has proved itself to be highly competitive with other framing systems, such as cast-in-place concrete in its various forms and structural steel and open-web joists.

COLUMNS

The key to the system is an unique precast concrete column and the method of effecting a column splice. The columns are always single-story units, thus making it necessary to have a column splice at each floor. The columns are reinforced with a hot-rolled, seamless structural steel tube running longitudinally in the center of the column. The inside diameter of this tube or column core is held constant at 4 in.; the wall thickness is varied to suit the load requirements. The percentage of steel is in the range of $\frac{1}{2}$ of one percent to 6 or 8 percent of the gross cross sectional area of the column.

A group of Dyna Frame columns awaiting shipment are shown in Fig. 1. The black band around the edge of the column is a $\frac{1}{2}$-in. strip of neoprene which is glued to the top of the column in the plant. End plates
Fig. 1. Precast columns in storage

are shown clamped to several cores in Fig. 2. The wire coil around the core will be stretched out in the form to serve as column ties. Tests have shown that the presence of these ties has little or no effect on the capacity of the column, but they improve the mode of failure at ultimate load. After attaching the end plates, the assemblies are placed end to end in long U-shaped forms prior to casting the columns.

Three ¼-in. prestressing strands are strung the full length of the 65-ft. long form, then tensioned against the ends of the form itself. The wire coils are spread out between the end plates of the individual columns with the coil being centered in the column by the three strands. The concrete is cast and screeded flush with the top of the form. After curing, the tie support strands are cut between each column, the columns lifted out of the form, the end plates removed, the neoprene gaskets applied to the tops of the columns and the pieces marked and ready for erection. The small amount of pre-stress given to the columns by the three support strands is helpful in resisting flexural stresses in the column during stripping from the form and in handling long columns.

The only information that the plant needs to produce a Dyna Frame column is the cross section dimension of the column and the size and length of the core. This information is put on a standard IBM punch card with one card per column. These cards are operated on by various control programs. Material order lists and form layout instructions are the most important of these programs. With proper equipment it would be possible to cast the columns in long lengths for stockpiling,
then saw off pieces as required. Interaction curves have been developed for 12 x 12-in., 16 x 16-in., 20 x 20-in. and 24 x 24-in. columns for a broad range of core sizes. Fig. 3 shows a simplified form of the 16 x 16-in. chart. The validity of the column design has been verified by an extensive testing program on full-sized columns at Lehigh University.

BEAMS

The floor and roof beams always sit on top of their supporting columns, never frame into them. This condition permits the designer a great deal of freedom in the design of the beams. He can design using simple span beams as shown in Design “A”, Fig. 4, multi-span beams as in Design “B”, or in a semi-cantilevered configuration with beam splices at or near the natural points of inflection as in Design “C”, or a combination of all three. Because of the mechanical aspects of the column splice, butting the beams over the column as shown in Design “A” is to be avoided. If simple span beams were desired, the beam splice would be located at the face of the column. In other words the same as Design “C” with the length of the cantilever being zero.

The beams are conventionally pre-stressed with straight strands. In Designs “B” and “C” there is both positive and negative bending moments present in some of the beams, therefore the straight strand has to be closer to the neutral axis than in Design “A”. This reduced eccentricity

![Fig. 3. Interaction diagram for a typical column](image)

![Fig. 4. Possible beam arrangements](image)
in the prestressing force eliminates camber and camber growth problems, and at the same time reduces live load deflections. In practice the beams are dead level.

The beam shown in Fig. 5 was cast as a single multi-span unit 57 ft. long. It is a second floor beam over a parking level of an 8-story motel in Washington, D.C. This beam is quite heavily prestressed, but the straightness of the member is apparent.

In general the beams are designed as composite members (Fig. 6). The precast portion has to take the erection loads of the floor plank, concrete topping, and its own dead weight for both negative and positive moments. The total section is checked for the ultimate load condition. Mild steel is added over the columns in the field-cast composite top to take the ultimate negative moment imposed on the beam.

**BEAM CONNECTIONS**

There are two basic connections for the beams—one is at the column, the other being the beam splice.

**Beam-column connection.** For the erection loads the beam sits on the neoprene strips on top of the column. These strips will accommodate any camber, twist or unevenness that might exist. The beam sleeve is a 6-in. round inside diameter length of standard pipe which is cast in the beam to be concentric with the core of the supporting column (Fig. 7). The space between the bottom of the beam and the top of the column is grouted, but not until after all floor plank have been erected.

When erecting a beam soffit, a special aluminum cone is set on top of the column and the beam is lowered over the cone (Fig. 8). The cone guides the beam into proper position on the column. The diameter of the base of the cone is about \( \frac{3}{8} \) in. less than the diameter of the
Fig. 7. Beam to column connection detail

Fig. 8. Use of erection cone

beam sleeve. After the beam has been seated the cone is pulled up thru the beam sleeve completing the erection connection.

Fig. 9 shows a three-span beam being lowered over the cones on top of four supporting columns. The beam is guided into approximate position with tag lines; the cones do the rest of the work. It is mandatory that the beam sleeves be accurately located as there is no allowance for field adjustment using this erection procedure.

Beam Splice. The connection angles and load support bolts of the beam splice (Fig. 10) are designed to take the entire reaction of the supported beam. The connection angles are located in the composite top of the beam between the ends of the floor plank. The design of the load support bolts and their internal anchorage is patterned after the normal tee-hanger connection. As the connection is exposed from the top during erection, the crane can place the beam in position and let go. Lateral alignment can be done with pinch bars and vertical adjustment with the nuts on the load support bolts.

Except where a slip or expansion joint is desired, the mild steel negative moment reinforcement is extended through this joint a sufficient distance to insure an adequate tie
between beams. No attempt is made to transfer moment through this connection.

In addition to standardized beam sizes the forming system developed for the beam depends on two major considerations:

1. All attachments, bolts, sleeves or any other hardware required to be cast in the beam has to be supported in the form from above. The beams are cast in the same U-shaped steel forms as the columns. There is no provision for attaching anything to the sides or bottom of these forms.

2. All plan dimensions are to be full inches. No fractions of inches in column or beam spacing can be accommodated.

In practice these restrictions have not caused any apparent concern to either the architect or engineer.

**BEAM MANUFACTURE**

The starting point in beam casting is a pair of 12-in. channels (Fig. 11) the length of the U-shaped form. Holes drilled in the top flange are 3 in. on centers and the accuracy in drilling these holes is extremely critical. The holes are numbered consecutively from No. 1 for the first hole to No. 259 for the last hole in a 65-ft. long channel. All hardware that has to be cast in the beam, as well as the bulkheads that form the ends of the beam, are attached to these channel rails.

Fig. 12 shows the bridge, that positions a beam sleeve, attached to the channel rails. The holes in the top plate of the bridge are 1 in. on centers and the bolts are in the right hand pair of holes. If the bolts went through the center hole the beam sleeve would be positioned 1 in. further down the form. This arrangement of 3-in. spacing of holes in the rails and 3 holes at 1-in. spacing in the bridge enables inserts to be located at any place along the rails in 1-in. increments. This location can be fixed simply by noting the number of the hole in the rail and whether the right, center or left
The end bulkhead bridge (Fig. 13) has a sheet of plywood the size of the beam attached to the face of the bulkhead. This plywood sheet is drilled for the actual strand pattern to be used for the beam. These holes fall over the strand slots in the bulkhead bridge. The man in placing strand simply fills all the holes.

When the bulkhead bridge is used as a divider between two beams, a plywood cover is used on both sides of the bulkhead. After the concrete has taken its set, the tie support strands can be cut and the bulkhead removed without disturbing the beam strand, leaving a space between the covers for cutting the beam strand after the concrete has reached its required release strength.

These bulkhead bridges also hold and locate the channel rails in their proper position. All the various bridges required for a form are attached to the rails, the proper number of ties are bunched between the individual bridges, the strand is threaded through the holes in the bulkhead covers, and the whole assembly is picked up and placed as a unit in the U-shaped form. The strand is threaded through the stressing grillage at each end of the form and then tensioned. The ties are spaced out between each bulkhead by visual reference to the numbered holes in the rails.

A plan view of a section of the rail assembly (Fig. 14) shows how the various elements are placed. The bridge at the left side of the drawing is an end bulkhead. The right side can be turned to show a division between two beams.

Fig. 13. Detail of a bulkhead bridge

Fig. 14. Plan view of rail assembly
hand bridge holds a beam sleeve which would be located at the center of a column. The required ties are No. 4 @ 9 in. o.c., or one every third hole. The holes in the portion of rail shown here are numbered 5 through 31. The computer output sheet would give the form assembly instructions in a manner similar to that shown under the rail hole numbers. Detail “A”, which is the standard end bulkhead bridge, is bolted through the left hand hole in the bridge and through hole No. 6 in the rail. Detail “B”, which is the standard beam sleeve bridge, is bolted through the right hand hole and through hole No. 24 in the rail. The end of a beam is always 1 in. from the centerline of the bulkhead bridge. Attaching the bridges in the positions specified on the assembly instructions would result in the center of the beam sleeve being 4 ft. 3 in. from the end of the beam. The assembly instruction sheet also states that there are five ties located between the “A” and “B” bridges and that the first of these ties is located at hole No. 9. The ties are to fall on every third hole so they are spaced at 9 in. o.c. The assembly instructions also show that there are to be 15 ties between the “B” bridge and the next one on up the rail with the first of these ties located at hole No. 26. Thus, all the information for the beams to be cast are given in reference to standard details and to numbered and lettered hole positions in rails and bridges. These instructions are developed directly by a computer program based on input in the normal form of feet and inches and, like the columns, one IBM punch card per beam. In other words, no shop drawings per se.

Fig. 15 shows a cross section of the U-shaped form with the channel rail assembly in place ready for casting a beam. The concrete is leveled to the bottom of the channel rails which forms the bearing surface for the floor plank. Strands above the top of the beam are the tie support strands. The height of the ties above the top of the beam can be adjusted in increments of 2 in.

COLUMN SPLICES

In the erection of columns, a threaded pipe or spindle with a constant 4-in. outside diameter, projects up out of the footing. Again, like the column core, the wall thickness is varied to suit the load requirements. A short length of tubing, called the collar, is threaded down over the spindle. Its outside diameter is the same as that of the core in the column above. The collar is adjusted to the proper elevation and the column is slipped down over the spindle until the bottom of the core bears on the top of the collar. The spindle projects about a foot up into the core of the column. This is sufficient to support the column during the erection phases that follow. The column remains in this condition until the framing of the floor above has been set, then the bottom of the column is dry-packed or grouted with a non-
shrink grout to complete the connection. The erection of column splices is identical at intermediate floors of a tier building.

A Dyna Frame column splice (Fig. 16) at an intermediate floor level is developed in the following sequence in the field:

1. The lower column, with the neoprene gasket in place, has been erected and adjusted vertically to the proper elevation.

2. The beam soffits are erected over temporary erection cones, which are then removed.

3. The floor plank are erected.

4. The spindle, with the lower collar threaded on, is slipped into the core of the lower column. The collar prevents the spindle from slipping all the way down the column.

5. Grout “A” is poured down through the beam sleeve and flows out in the space between the bottom of the beam and the top of the column. A small vent tube is located at each corner of the gasket to allow the trapped air to escape.

6. The bottom of the lower column is grouted at this time.

7. The upper collar is threaded down over the spindle to the proper elevation.

8. The upper column is slipped over the spindle.

9. The beams and floor plank of the floor above are now erected as was described in the preceding steps.

10. Grout “B” is placed.

These steps complete the erection phases of the connections. At a later date, at the contractor’s convenience, the plank topping and the infill between the ends of the plank, which forms the composite top of the beam, is placed to complete the structural floor slab.

Dyna Frame can be summed up as a structural system that 1) uses manufacturing techniques in the production of the units; 2) erects in a continuous operation without dependence on other trades; 3) produces a dimensionally accurate, structurally sound building free from fussy details; 4) is adaptable to a wide variety of building types; and 5) can be quickly and economically designed by the average consulting structural engineer without an extensive background in precast structures. Dyna Frame appears at this time to have a lower cost factor than exists elsewhere in the building industry for fire rated structures.

Fig. 16. Erection detail for a column splice

Discussion of this paper is invited. Please forward your discussion to PCI Headquarters before April 1 to permit publication in the June 1969 issue of the PCI JOURNAL.