Machine to Apply Repeated Loads to Large Flexural Members

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A research program being conducted at Lehigh University to investigate the endurance of prestressed concrete bridge members necessitated the development of a testing machine which would apply a repetitive load to simulate the passage of trucks moving at various speeds over a bridge member. Special machines of this type are available in Europe and used in different laboratories abroad. However, it was intended to build such a unit, using only standard parts of equipment available in this country. As this machine is believed to be unique and since others may find it useful, it is described herein. The performance of the machine has been demonstrated by the application of 2,500,000 cycles of loading to two concrete beams, one of which is shown under test in Fig. 1.

DESCRIPTION OF TESTING MACHINE AND LOADING FRAME

The testing machine consists of a loading frame, two hydraulic jacks, and a pumping system.

Loading Frame:

As shown in Fig. 1, two 36-in. WF sections 38 ft long, provided with the necessary stiffeners, are spaced 3 ft apart and connected together by means of cross-bracing and diaphragms. Acting as a unit, this base frame is simply supported at the ends, carries the test beam, and provides anchorage for the

New to this country—a testing machine that simulates the passage of trucks at various speeds over bridge members.

two hydraulic jacks. Furthermore, two cross members fixed on the base unit can be adjusted to support any length of test beam up to 38 ft at an elevation of 3 ft above the base frame.

The simply-supported end conditions of the test beam are provided by a hinge at one end and a rocker at the other.

The two hydraulic tension jacks are placed at the third-points of the base beam. Each is connected to an adjustable yoke in such a manner that the load is applied at the top of the test beam.

Jacks:

Although the jacks can occasionally be used to produce up to 100 kips (a kip equals 1000 lb) of static load, they were built for a maximum working capacity of 50 kips. They are standard jacks and were not designed for dynamic use.

To determine the applied load, strain gages are mounted on the rods connecting the jacks with the yokes. To record the magnitude of the load, a type K, Baldwin Indicator is used during

![Fig. 1.—General View of the Testing Machine with a Bridge Member in Place.](image-url)
Fig. 2.—Loading Phase of Cyclic Loading Machine.

The main parts of the pumping system consist of an oil tank, a 50-hp electric motor, a high-pressure oil pump, a system of valves connected with high-pressure pipe lines, an electronic timing device, and all the necessary control instruments.

Pump.—This high-pressure pump is an axial piston type designed for 5000-psi maximum pressure. By changing the length of the stroke of the pumping pistons, the volume of delivered fluid is regulated by automatic control. The maximum capacity of the pump is 20 gal per min.

Powered by an electric motor at 1200 rpm, the pump draws oil from the tank and delivers it to the pressure line which is connected with the jacks.

Four-Way Valve.—Included in the pressure line is a four-way valve, which in turn is connected with two separate low-pressure lines leading into the oil tank. A solenoid, controlled by an electronic timer, shifts the spool of the four-way valve alternately in two different positions.

In the first position, the pressure line from the pump is connected with the pressure line to the jacks. The pressure in the jacks is then built up and consequently the load is applied to the test beam, while the low-pressure lines are connected together without any resulting action (Fig. 2).

In the second position of the spool, the pressure line coming from the pump is connected with one of the low-pressure lines. The oil flows from the pump through the four-way valve into this line and back into the tank without doing any work. At the same time the pressure line joining the jacks with the four-way valve is connected with the second low-pressure line. As the oil goes through the four-way valve back into the tank, the pressure in the jacks is decreased and the test beam is unloaded. The elastic rebound of the beam under test drives the pistons of the jacks back to their original position (Fig. 3). For special tests it is desired to apply alternating tension and compression forces on specimens. This can be accomplished by connecting an additional high-pressure line with the corresponding port of the four-way valve and the compression chamber of the jacks. The oil pressure by-passed during the unloading period in the present system could thus produce compression forces.

Sequence Valve.—The purpose of this valve is to regulate the working pressure in the system and thereby to control the loads applied to the test beam. This is accomplished by adjusting the valve to a desired pressure setting. No oil passes through this valve until pressure in the main line exceeds the pressure setting. When this condition is reached, the valve automatically by-passes the excess oil into an additional line connecting it to the relief valve (Fig. 4).

Relief Valve.—As mentioned above, an automatic control regulates the volume delivered by the pump. This control is located in the base of the pump and consists of a pressure-operated cam that regulates the length of the pumping stroke of the pistons. This is a comparatively low-pressure device with a maximum working pressure of 300 psi.

To prevent excessive pressure in the control, a relief valve is installed between the sequence valve and the pump. This valve maintains the pressure to the pump control within its safe working range and, by adjustment, permits additional control of the complete system. Oil that is not required to maintain the adjusted working pressure of the relief valve is by-passed directly to the supply tank (Fig. 4).
Surge Valve.—With each operation of the four-way valve, the pressure in the system changes rapidly. Especially in the unloading phase when the jacks are connected with the supply tank, the working pressure drops suddenly to zero. To prevent a hydraulic hammer, a surge-damping valve is placed between the four-way valve and the jacks. Its function is based on the following principle:

When there is a sudden change of pressure, an orifice within the valve becomes smaller. This allows only a gradual acceleration of flow and dampens the shock of the released pressure.

In the loading phase, however, an undampened application of the increasing pressure is desired. This is provided by an additional line with a check valve, by-passing the surge valve. The check valve insures that in the unloading phase all oil is forced to flow through the surge valve.

Additional Valves.—Included in the pressure lines leading from the pump to the four-way valve are a globe valve and a check valve. The globe valve allows an additional adjustment of the oil volume and the rate of increase of the pressure applied to the jacks.

The check valve permits oil flow only in the direction of the four-way valve and therefore protects the pump from a possible back pressure.

Control Instruments.—For the control of the oil pressure, four pressure gages equipped with globe valves are connected with the system at the most important points.
Filters.—To keep the oil clean and free of foreign matter, which could seriously damage the pump and valves, two oil filters are placed in the system—a sump filter at the inlet of the pump and a micronic filter in the low-pressure lines coming from the four-way valve. The latter is connected to a by-pass including a relief valve for protection of the filter from excessive oil pressure.

Electronic Timing Device.—The two positions of the four-way valve are controlled by an electronic timing device. The loading and the unloading phase can be timed separately within a range between one quarter of a second and about 4 min. Included in this timing device is an electric counter which records the number of the load cycles. A schematic layout of the machine is given in Fig. 5. The front and back of the machine are shown in Figs. 6 and 7.

Performance of the Machine

For the tests of the two bridge members, the machine had to simulate the maximum magnitude and number of loads to be expected during the life-time of a corresponding structure. This was accomplished by applying an oscillating load of 17,700 lb at each third-point. By regulating the pressure and the volume of oil supplied to the jacks, as well as the periods of loading and unloading, a moment-time diagram for the center-line section was obtained, which was closely equal to that produced by the passing of a standard H20-S16-44 truck for which the bridge members were designed. The speed selected for these tests was 40 mph giving a load frequency of 1 cps. The corresponding moment-time diagram for the actual and the experimental loading is shown in Fig. 8.

After the inevitable adjustments and refinements of the trial phase were made, the machine has operated more than 700 hr and applied 2,500,000 loading cycles.

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