BRIDGE RECONSTRUCTION:
POLISH ENGINEERS PROVIDE ASSISTANCE AFTER 1,000-YEAR FLOOD

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The following article by staff at the Tadeusz Kosciuszko Military Academy, Wroclaw, Poland, describes the unexpected 1,000-year flood that inundated southern Poland in July 1997. The authors detail the flood's ruthless destruction of thousands of kilometers (km) of roads and numerous bridges that existed in the watershed. Polish engineers reacted quickly and lent military assistance to the immobilized countryside. The authors describe the engineers' experiences during reconstruction of the area's bridge infrastructure and explain the technical and organizational challenges they faced as well as the solutions employed. Lessons learned concerning the capabilities of small engineer bridging units are emphasized.

The 1,000-Year Flood

Prolonged and abundant rainfalls in July 1997 caused freshets within the southern part of Poland. Two flood waves that overflowed riverbeds and damaged or destroyed many bridges and road sections were especially severe. Based on the range of this disaster, it has been named the "Millennium Flood."

Destruction of Roads and Bridges

From the beginning of the flood to the end of July, the following main and local roads and bridges were excluded from traffic:

- 480 bridges, including 219 main road bridges and 261 local road bridges.
- 791 road sections, including 232 main road sections and 559 local road sections, with a total length of 3,172 km.

The greatest damage occurred in mountainous regions where roads are adjacent to rivers and streams. Many small bridges were built over rivers that run along main, local, and private roads to connect the roads to households. This parallel system of roads and rivers was the basic cause of the enormous devastation and damage to roads and bridges. The great mass and speed of the flood waves caused most of the destruction. Design flow values previously provided as permissible for bridges within Kotlina Klodzka, a mountainous valley in southwest Poland, were exceeded many times. Additionally, debris carried by flowing water plugged bridge clearances and increased stream speeds (velocities). As a result, the destroying force of water was intensified and caused stream bottoms to erode, especially at bridge supports.

In order to evaluate the kinds and causes of damage to bridges, engineers first must analyze the mechanisms that caused the damage. During the first phase of flood-destructive operations on bridge objects, we noted undermining and settlement of the bridge supports, and many of them finally collapsed (Figure 1). When that happened, the bridge spans broke, fell, and were destroyed. Fallen bridges and their support elements then barricaded the water beds, leading to increased stream speeds and the creation of new main water streams. The next result was undermining of stream banks and bridge access embankments, which caused the crowns on roads located along rivers to be washed away. We noted that

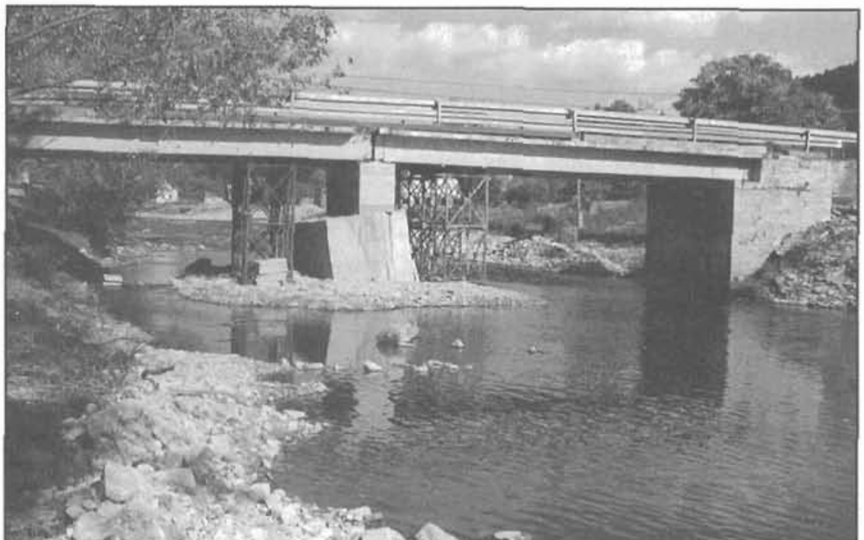

Figure 1. Lifted spans after the bridge broke due to undermining of its pillar. Note the significant settlement (approximately 1 meter) of the pillar and its dislocation (Radochów town - Baila Ladecka River).

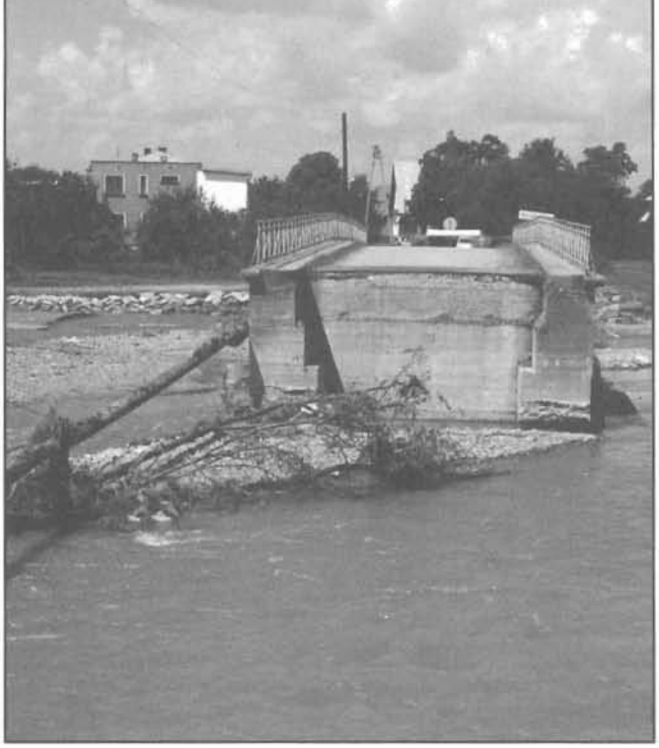

Figure 2. A washed out embankment behind a bridgehead. A 60-meter section of the access road was destroyed (Bystrzyca Dolna town - Bystrzyca River).

undermining of bridge supports caused the destruction of load-carrying members of all types of bridges except footbridges. Often, when bridge members withstood the water pressure, their access embankments were destroyed (Figure 2). At some locations new water beds were created (as at Radochów and Wilkanów). In many places, water mass created new, temporary riverbeds, which caused significant damage to areas along their routes. Bridge supports located in meanders of rivers and locations where bridges limited the natural stream width were especially exposed to undermining.

One example illustrating the elemental force of water is the 30-meter steel framework construction footbridge in Radochów. This footbridge was broken and moved a distance of 500 meters by floodwater. Water carried it over a broken bridge that lay in its way. *Destruction mechanism analyses show that proper protection of bridge supports against undermining is the most effective method of preventing damage. Bridge-support durability should be considered the main factor in designing and building bridges, because it determines the bridges' resistance to the destructive force of flood waves.*

Preparation for Eliminating Flood Consequences

For the temporary reconstruction of flood-damaged objects, the following units, specially trained for that purpose, were involved: military engineering units, military communication units, and civilian road- and bridge-building companies.

On 9 July 1997, as soon as falling water levels allowed, engineers started to identify and assess the damage and eliminate consequences of the flood. Due to persistently high water levels in rivers, impassable road sections, and the loss of communication with field units, it was difficult to assess the damage to roads and bridge structures.

During the first stage, immediately after the flood crest passed, the army assigned priority to the quick restoration of traffic along main transport routes. This was done by temporary reconstruction of the structures. By cooperating closely with civilian road services and municipal authorities, the army started to open passages in disrupted links. During the first stage, damaged bridges along main transport routes and national and local road sections were selected for repair.

Following the governor's request for assistance in repairing bridges and roads, a mobile team of military experts on transportation went to the zones affected by the disaster. Their task was to identify and evaluate the damage and indicate the technical and technological/organizational variants of their reconstruction. The goals of their reconnaissance were to determine the feasibility of using local materials, determine the military technical measures required, and assess field conditions (such as the condition of access roads and the possibility of deploying troops to the area of reconstruction).

The bridge reconstruction method chosen was largely determined by the following criteria:

- Degree of destruction.
- Significance and transportation requirements of the line the bridge was built on.
- Length of time the bridge will be in use.
- Available materials and structures.
- Capabilities of the engineering troops.
- Length of time assigned for reconstruction.

The basic requirements for bridges to be reconstructed included the following: limiting outline height (minimum 4.5 meters), roadway width (minimum 4.2 meters), and horizontal outline width where track spans were used (minimum 3.4 meters). Engineer experts adjusted the time of use of temporary bridges to match the characteristics of the road traffic, the obstacle type, and the anticipated time needed to replace temporary bridge structures with permanent structures.

The bridge reconstruction method selected was determined by the working requirements (people, materials, machinery, and engineering devices). Due to organizational conditions, engineers divided the entire work cycle into preparation and execution periods.

Preparation work included the following tasks:

- Engineer reconnaissance of bridge construction sites, places to prepare the materials and bridge structures, and supply paths.

- Removal of damaged spans and supports from the river bottom.
- Preparation and transport of structures and materials to the building site.
- Preparation of access roads and supply paths for materials and equipment.
- Preparation of building sites.
- Development of the work-mechanization measures and other devices needed to reconstruct the bridges.
- Preparation of design documentation.

The principal actions needed to execute temporary bridge reconstruction included the following tasks:

- Staking out the bridge axis.
- Constructing indirect and bank supports.
- Assembling the span structure and placing it on the supports.
- Constructing bridge entrances.
- Commissioning bridge use to local authorities and the road administration.

After determining the scope of the damage, engineers refined the concept of using military resources to eliminate flood consequences on the road network.

Bridge Reconstruction

To accelerate the pace of bridge reconstruction and quickly restore traffic continuity along main routes, engineers adapted the use of folding bridges (similar to Bailey bridges) and assault bridge structures for civilian traffic. The use of pontoon bridges was not possible in this mountainous area due to low water levels after the flood crests.

The DMS-65 folding road bridge, in the form of a free-supported beam, was the principal structure used to reconstruct destroyed bridge structures. Its theoretical span depended on land conditions. Essential components of the DMS-65 are spatial and flat elements of the main girder, transverse beams, the platform slab, and bolts to link particular segments of the structure.

Technical Characteristics of a DMS-65 Bridge

This bridge is meant for quick and multiple construction or reconstruction of destroyed high-water bridges. Using its components, it is possible to build single- or multiple-span bridges, with spans ranging from 3.0 to 45.0 m, and the change modulus 3.0 m in length. Due to the narrow width of water courses in Kotlina Klodzka, engineers reconstructed the bridges using single-span structures. A two-span continuous system was used only at Pilce (Figure 3).

The width of the roadway placed below or above is 4.2 meters, with a widening to 6.2 meters. The static system of the spans is assumed to be free-supported or continuous. The maximum span length under a load of 600 kilo-Newton (kN) (67.446 U.S. tons) is 39 meters for free-supported spans, 39 meters for outer continuous spans, and 45 meters for middle continuous spans. The maximum span length under a load of 800 kN (89.928 U.S. tons) is 33 meters for free-supported spans, 33 meters for outer continuous spans, and 39 meters for middle continuous spans. Bridge supports may be permanent (concrete), temporary, or floating.

Within three days, the army built a DMS-65 collapsible temporary bridge next to the destroyed bridge at Roztoki (Miedzylesie Commune, Figure 4, page 14). The road the bridge is built on is an important transport route from Warsaw to Prague and Vienna. Numerous local businesses and thousands of motorists use this road every day. Similar structures were built at Gajnik and Goworów.

The structure at Roztoki has the character of a temporary bridge but will function until a permanent bridge is built. A permanent bridge is planned at Roztoki as a gift for flood victims. Local societies will use the bridges at Gajnik and Goworów for the next few years. The bridge at Gajnik has steel pipe abutments and a retaining wall. This solution should make the supports resistant to future washout and make it prospectively possible for a future permanent bridge to be supported on them. *To make the roadway level with the bridge formation line for smooth passage, it was necessary to lower the bridge bearings below the surface level and apply an intermediate slab in the form of a 3-meter entry span.*

Figure 3. A bypass bridge made of DMS-65 structure elements with a continuous beam of 33 meters + 33 meters in length and access spans of 3 meters in length. The remaining parts of a destroyed bridge of 59 meters in length (Pilce town on the Nysa Klodzka River) are shown in the foreground.

Figure 4. Free-supported spans in a DMS-65 structure in the basic arrangement. It has a 21-meter span with 6-meter entry spans stretching Lc = 7 meters (Roztoki - Miedzylesie Commune on the Nysa Klodzka River).

Technical Operating Characteristics of BLG and SMT-1 Assault Bridges

BLG and SMT-1 bridge spans are track structures that are laid directly on an obstacle (see table below). They are principally used for single-span bridge construction. These bridges allow pedestrians and wheeled and tracked vehicles to pass the obstacle. The structures should be supported on strong subsoil and protected from washout or slide. The length of support on reinforced banks is at least 0.50 m.

To increase vehicle and pedestrian safety, engineers increased the limited width and free space left between the tracks and installed handrails. An unquestionable advantage of these adaptive solutions is that both assembly and disassembly can be performed quite quickly (Figures 5 and 6, page 15). These adaptations made it possible to perform the repair quickly and to restore the span's military functions.

Engineers used a BLG span discarded by the army to build a bridge at Kletno. They built up the intertrack space using steel plates that were welded to track edges and supported on steel crossbars that were welded to track structures. In addition, the engineers made channel-bar steel curbs and angle-bar handrails (Figure 5c, page 15). While the reduced width of the span (3.20 m) fails to meet the requirements for tracked bridges, the ability to build the bridge quickly was a decisive factor in using this method.

In other places, temporary reconstruction was performed or low-water bridges were built in cooperation with local authorities using local materials.

Conclusions

The following conclusions are based on experience gained during the 1997 flood:

- The order in which destroyed roads and bridges were to be reconstructed depended on how quickly the water level fell and how significant the bridges and roads were for transportation. The priority was for temporary (immediate) reconstruction using local materials and military resources.
- Where lasting damage was revealed but did not yet threaten bridge stability, officials allowed traffic to cross the structures under certain limitations until comprehensive reconstruction was performed.
- Where bridge structures had been totally destroyed by the flood and required comprehensive reconstruction, engineers recommended a detailed analysis and assessment of the disaster causes. Conclusions drawn from the analyses and assessments were used to help avoid repeating the same or similar mistakes when reconstructing or building bridges.
- Where bridges were destroyed, engineers made road detours for the shortest access to dwellings and business places. Engineers also constructed temporary bridges made of wood or used collapsible steel structures stored in so-called "transport reserves" of the State. These temporary measures should work until permanent bridges are built.
- Assault and folding bridges may have wide applications outside of the military community, especially when

Technical Operating Characteristics of BLG and SMT-1 Spans

Parameters	Armored Vehicle-Launched Bridge (BLG-67)	Wheeled Vehicle Assault Bridge (SMT-1)
Width of land obstacles to be passed	Up to 19 m	6 to 10 m
Number of directions	One-way traffic	One-way traffic
Load-bearing capacity	150 kN (16.86 t) for wheeled vehicles and 500 kN (56.21 t) for tracked vehicles	110 kN (12.36 t) for wheeled vehicles
Span length	20 m	10.5 m
Span width	3.25 m (BLG-67M2 - 3.43 m)	3.30 m
Number of tracks	2	2
Track width	1.15 m (BLG-67M2 - 1.24 m)	1.20 m
Distance between tracks	0.95 m	0.90 m
Span weight	60 kN (6.74 t) (BLG-67M2 - 70 kN or 7.87 t)	29 kN (3.26 t)

BLG-67M2=New model.
kN = kilo-Newton. 1 kip = 4.448 kN; 1 U.S. ton = 8.896 kN.

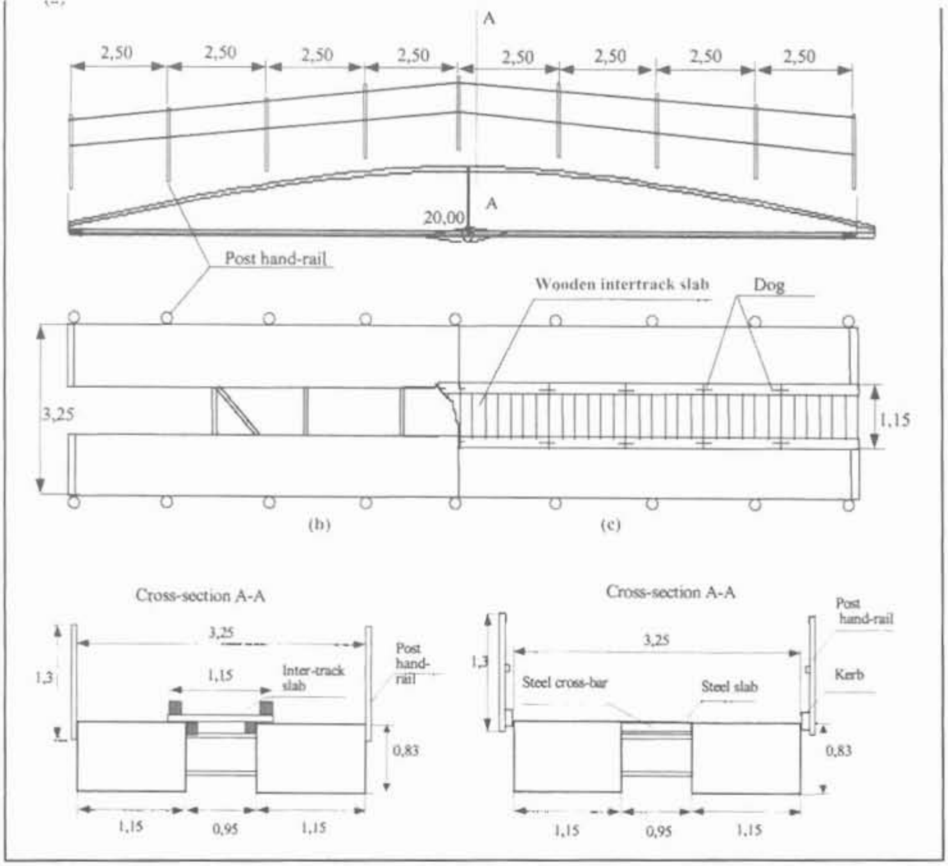

Figure 5. A scheme for building up a BLG span: (a) and (b) use wooden intertrack slabs, and (c) uses steel intertrack slabs.

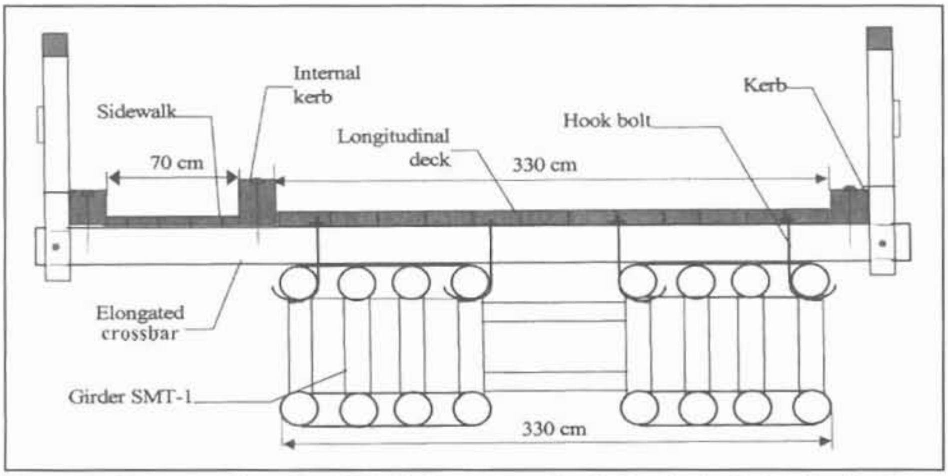

Figure 6. Cross section of an SMT bridge span. The bridge is built longitudinally with a wooden deck on crossbars.

repairing damage from disasters or accidents, and have enormous benefits to society.

Engineers generally should design new bridges with longer spans than those used in the past. They should properly protect riverbanks and bridge supports against washout (undermining). Additionally, civilian and military authorities should prepare detailed plans for their cooperation when working to prevent flood damage and when cleaning up after a flood or other disaster.

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