BRANCH FAILURES: A CLOSER LOOK AT CRACK DRYING

by Alex L. Shigo

Abstract. Branch failures are major causes of damage to property and power lines and of injury to people. The purposes of this paper are to discuss briefly the different ways branches fail, and to present a hypothesis that crack drying may lead to branch failure.

Résumé. Les bris de branches sont une cause majeure de dommages à la propriété et aux réseaux électriques, et de blessures aux individus. Les buts de cet article sont de discuter brièvement les différentes manières qu'une branche peut briser, et de présenter une hypothèse que les fentes qui se dessèchent peuvent conduire à des bris de branches.

Branches are attached to trees by a series of collars. Trunk collars form over branch collars. The arrangement of collars gives the living branch great strength.

Branches are shed after they die. A chemical boundary that resists inward spread of pathogens forms within the branch collar at the base of the branch. Decay develops from the dead branch toward the boundary, but usually does not develop beyond the boundary. The branch becomes weakened because of the decay, and loading by wind, ice or snow cause the branch to fail.

Branches on trees in a natural forest usually die when they are small. Forest trees have long, narrow trunks. Branches on trees grown in the open usually remain alive low on the trunk. The architecture of forest trees is different from the architecture of the same species of tree grown in the open.

Branch Failures

Branches on any tree will fail when loading exceeds the resistance of the wood. Branches will also fail when a weakened area on the branch gets weaker even when loading remains constant.

Let us discuss these points further. When a branch is frozen and loading increases beyond the resistance of the wood, the branch usually fails or fractures near the base but not at the base. A long splintered stub will remain. When the same branch is not frozen and loaded beyond its resistance, the branch usually pulls out of the trunk. A spindle-shaped section of the trunk is usually at the base of the branch.

When large branches are tip pruned, sprouts often form and grow upward and outward from the end of the branch. The loading on the residual branch may remain the same but the weight is now shifted outward beyond the end of the branch because of the vigorous growth of the sprouts. The sprouts have a weak attachment to the end of the branch. Moderate loading on the sprouts could cause failure.

Branch Weak Spots

The next point is an extremely important one. When a weak spot gets weaker, a branch could fail even when there is no additional loading. Weak spots may result from death of branches on the larger branch, from cankers, wounds made by birds, insects, animals, or hail or by improper pruning cuts that removed the branch collar—flush cuts. Weak spots may also develop in the trunk that supports the branch. And again, the trunk weak spots could result from cankers, cracks, and a great variety of wounds. The trunk weak spots may also be associated with dead or dying roots.

When any weak spot on the branch or trunk develops to the point where the weight of the branch exceeds the holding power of the weak spot, the branch will fail.

Included bark. Another type of weak spot is included bark. This can be a serious problem for trees that have many large branches at the same position on the trunk. The problem starts when the branches start growing rapidly in a near horizontal direction.

Cracks and Wetwood

The most serious weak spot is the most difficult to understand as a weak spot. It is the weak spot associated with internal cracks and wetwood.

1. Presented at the annual conference of the International Society of Arboriculture in Vancouver, B.C. in August 1988.

Where do the internal cracks come from? They come from wounds, and the major wound is the flush cut. But before we discuss the flush cut, it is important to review briefly how cracks develop in trees.

After wounding, reaction zones form that resist spread of pathogens into the wood. The still living cambium about the wound forms cells that differentiate to form a barrier zone. The barrier zone separates wood present at the time of wounding from new wood that continues to form. The barrier zone is a strong protective zone but a weak structural zone. The barrier zone may separate to form circumferential shakes when pressures of drying, felling, or bending occur or when there are sudden changes in temperature.

When callus grows rapidly at the sides of a wound, the edges of the callus may roll inward. The inward rolling callus may start vertical seams or cracks at the edges of the wound. As the callus grows over the wound from the sides, a vertical seam or crack often develops. This is called the primary crack. The cracks that may form where the callus rolled inward are called the secondary cracks. When pressures of drying, felling, or bending occur or when there are sudden changes in temperature the cracks may spread outward.

Wetwood is a common disease associated with the cracks and the wood about the cracks.

There is no way that a tree can stop outward development of cracks when pressures of drying, bending, or felling occur, or when there are sudden temperature changes. Reaction zones form that resist lateral spread of infections associated with the cracks.

I have cut hundreds of oaks and other hardwoods that have had many shakes and vertical cracks. I have never seen a trunk fail in the forest that had many internal cracks with wetwood. Wetwood was common in the cracked trees. Liquid would often flow outward as the tree was cut.

I have seen balsam fir trunks fail that had vertical cracks. Where trunks had failed, decay was in the trunks. When the trunks were cut, the wood was dry.

A Hypothesis

From these observations over 30 years on hundreds of trees came the hypothesis that wetwood in cracks may keep trunks from breaking. To test the hypothesis, I took stems approximately 2 cm. in diameter and 50 cm. long from several species of hardwoods and softwoods. In the center, I cut a 5 cm. long "crack" with a knife to 0.5 cm. deep. Another "crack" was cut 180 degrees in the stem. Then I applied pressure to bend the stem against a wall. The stems bent completely together without breaking. Then I repeated the procedure by applying only enough pressure to bend the stems slightly. I took a hair dryer and blew hot air on the cracks. The stems cracked.

Indeed, a very crude experiment that needs refinement. It does suggest that crack drying may be an important factor affecting trunk and branch failure.

Flush cuts. Back to flush cuts on large branches. The cuts often lead to circumferential and vertical cracks. When loading on such cracked branches increases, the branch may split internally to form two beams. When one beam begins to move over the other, the branch may shear. Or, loading may not increase, but crack drying does take place. Then it is possible to have branch failure without wind, or rain, or any other loading agent.

The hypothesis will be tested soon by engineers at the University of New Hampshire. For more details and many photographs on the subjects discussed here, see A New Tree Biology (1).

Literature Cited

1. Shigo, Alex L. 1986. A New Tree Biology. Shigo and Trees Associates, Durham, New Hampshire.

Alex L. Shigo
Shigo and Trees, Associates
4 Denbow Road
Durham, New Hampshire, U.S.A.