Structural failure profile: Italian stone pine (*Pinus pinea*)

L. R. Costello, J. Tso, and K. S. Jones

EACH YEAR, THE STRUCTURAL FAILURE OF trees in urban and forested recreation areas results in personal injuries and property damage. A key objective of a tree management program is to reduce the potential for failure to the extent possible. One important element of failure reduction strategies is to prevent or mitigate conditions that may lead to failure, such as pruning branches weakened by wood decay, cabling or bracing, and avoiding root damage.

All tree species do not fail in similar ways, however. Some are prone to fail as a result of weak architecture, such as codominant stems. Others have a greater propensity to fail because they develop large end-weights on branches --- exceeding the load tolerance of the wood. Knowing the particular failure patterns of species can help tree managers identify key defects that may lead to failure.

By collecting detailed information following the failure of a tree, data can be compiled and then used to develop structural failure profiles for species. Such a profile has been developed here for Italian stone pine (*Pinus pinea*) using data from the California Tree Failure Database (CTFD). Arborists and foresters can use this information to develop structural management strategies for Italian stone pine. The development of this profile was commissioned by the Britton Fund of the Western Chapter of the International Society of Arboriculture.

Figure 1. Italian stone pine is a relatively common landscape tree in California. Typically, it has a rounded crown and multi-stem structure. *Photo: K. Jones.*

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Italian stone pine distribution

Italian stone pine is native to southern Europe and Turkey, but has become naturalized in many regions with a Mediterranean climate. It is a relatively common landscape tree in California, being found in both public and private landscapes (Fig. 1).

General statistics

There are a total of 170 reports in the CTFD for Italian stone pine, the majority of which are for root failures (41%). Trunk failures comprise 30% of reports, and branch failures make up the remaining 29%.

Reports came from 22 counties, but the majority (75 reports) are from Contra Costa, San Francisco, and Santa Clara Counties. Italian stone pine failures are slightly more common in winter than summer, with 52% of failures reported from December to February. General statistics for all failure types can be found in Table 1.

Table 1. General statistics for all failure types.

Variable	Mean
Age	43 years
Height	47 feet
DBH	32 inches
Crown spread	44 feet

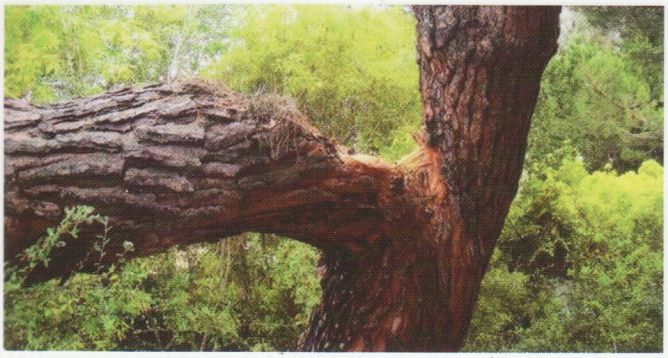

Figure 2. Many Italian stone pine branch failures occur at the attachment, rather than along the branch. Heavy lateral limbs (end weights), dense crown, and multi-stem structure were reported to be associated with branch failures. *Photo: C. Rippey*

Most failed trees were found in a group (57%), in high use areas (59%), and in residential areas (36%). The most common defect for all failures was dense crown, observed in 21% of reports, followed by multiple/codominant trunks (20%) and leaning trunks (15%).

A. BRANCH FAILURE

Branch failure was reported in 50 cases, or 29% of all reports.

Branch failure location

The majority of branches failed at the attachment (60%) (Fig. 2). Failures along the branch occurred largely within 3' of the trunk (40%), with diameter of the break highest in the 5-12 inch range (60%). The majority of trees with branch failures were between 26 and 50 years old (59%).

The main structural defects observed in trees with failed branches are heavy lateral limbs (observed in 43% of cases), dense crowns (21%), and multi-stem structure (15%) (Table 2).

Decay and branch failures

Decay was reported in only one branch failure case, less than 25% of the cross-sectional area was decayed, and a sporophore was not found. All other reports, comprising 98% of total cases, reported no decay.

Wind and branch failures

Although more failures occurred in low wind conditions where wind speed did not exceed 5 miles an hour (35%), failures were distributed quite evenly across low, moderate, and high wind speeds (Table 3).

Table 3. Wind speed and branch failure.

Wind speed	Frequency of occurance
Low wind (<5 mph)	35%
Moderate wind (5-25 mph)	32.5%
High wind (>25 mph)	32.5%

Precipitation and branch failures

The majority of branch failures occur during dry conditions (62%), while the remainder occurred during a precipitation event.

Pruning and branch failures

Pruning had not been done in 63% of branch failure cases, while 28% of cases indicated that the tree had been thinned. The remainder of reports did not indicate whether pruning had been done or not.

B. TRUNK FAILURE

Trunk failures accounted for 30% of Italian stone pine failures. Most occurred above ground level (55%), while the remainder (45%) occurred at ground level. Trunk diameter at the point of failure ranged from 7 to 54 inches, but the majority (44%) were between 13 and 24 inches in diameter. The primary defect associated with trunk failure is multiple trunks/codominant stems, observed in 44% of cases, followed by dense crown (28%) (Table 4 and Fig. 3).

Decay and trunk failure

Decay was not present in 76% of trunk failure cases (Fig. 4). In 90% of cases where decay was found, less than 50% of the cross-sectional area was decayed. Sporophores were observed at the point of failure in only two trees, or 4% of cases.

Table 2. Defects reported associated with branch failures.

Defect	Frequency
Heavy lateral limbs	43%
Dense crown	21%
Multi-stem	15%

Table 4. Defects reported associated with trunk failures.

Defect	Frequency
Multiple trunks/codominant stems	44%
Dense crowns	28%
Leaning trunk	8%

Figure 3. (Above) Codominant stems and multiple trunks were the most commonly reported defect causing trunk failure in Italian stone pine. Here, a large comdominant stem failed at the point of attachment. Embedded bark is not commonly found in such failures in *P. pinea*.

Figure 4. (Below) Decay was not present in 78% of trunk failures, but dense crown was reported to be a key factor. Here, an Italian stone pine with a dense crown failed at a point high on the trunk. No decay was evident.

Precipitation and trunk failures

Slightly more than half (54%) of trunk failures occurred during wet conditions, while the remainder of cases occurred during dry conditions.

Wind and trunk failures

Trunk failures most commonly occurred during low wind conditions between 5-25 mph (40%), but distribution was fairly even across low, moderate, and high wind conditions (Table 5).

Table 5. Wind speed and trunk failure.

Wind speed	Frequency of occurance
Low wind (<5 mph)	40%
Moderate wind (5-25 mph)	28%
High wind (>25 mph)	32%

Figure 5. (Above) The most common type of failure in Italian stone pine is uprooting. Although dense crown is frequently associated with root failures, decay is not. *Photo: C. Llata.*

Figure 6. (Below) Girdling roots are reported to contribute to a number of failures in Italian stone pine. Here, a girdling root occurring at ground line was linked to the failure of this Italian stone pine. *Photo: C. Rippey.*

C. ROOT FAILURE

Root failure is the most common failure type, with 69 reports, or 41% of the total (Fig. 5). Trees experiencing root

Table 6. Defects reported associated with root failures.

Defect	Frequency
Leaning trunk	29%
Kinked/girdling root	18%
Dense crown	15%

Table 7. Wind speed and root failure.	
Wind Speed	Frequency of occurrence
Low wind (<5 mph)	30%
Moderate wind (5-25 mph)	23%
High wind (>25 mph)	47%

failure ranged from 7 to 100 years old, with the majority (76%) aged 11-50.

Defects and root failures

The most common defects were lean (29%), kinked or girdling roots (18%), and dense crown (16%) (Table 6 and Fig. 6).

Decay and root failures

Decay was not present in 67% of root failure cases. Fruiting bodies were observed near the failure location in only 16% of trees with decay.

Wind and root failures

The majority (47%) of root failures occurred during high wind conditions, while 30% and 23% of failures occurred under low and moderate wind speeds, respectively (Table 7).

Precipitation and root failures

Precipitation was reported in 67% of root failure cases. Saturated soil conditions were reported in 32% of cases.

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Summary of Key Findings

- Root failure is the most common type of failure in Italian stone pine (41%).
- The majority of branch failures (60%) occur at the point of attachment.
- Heavy end weight, dense crown, and multi-stem structure were key factors contributing to branch failures.
- Multiple trunks/codominant stems, dense crown, and lean were key factors contributing to trunk failures.
- Lean, girdling/kinked roots, and dense crown were key factors contributing to root failures (Fig 7.).
- Decay was not present in the majority of branch, trunk, and root failures.
- Where decay was present, sporophores (fruiting bodies) were rarely found.
- Embedded bark was reported in only 4% of trunk and branch failures.
- Root failures were associated with precipitation and saturated soils, while trunk and branch failures occurred almost as frequently during either dry or wet conditions.
- Wind played a role in the majority of root failures (47%), while branch and trunk failures were distributed fairly uniformly during low, moderate, and high wind conditions.

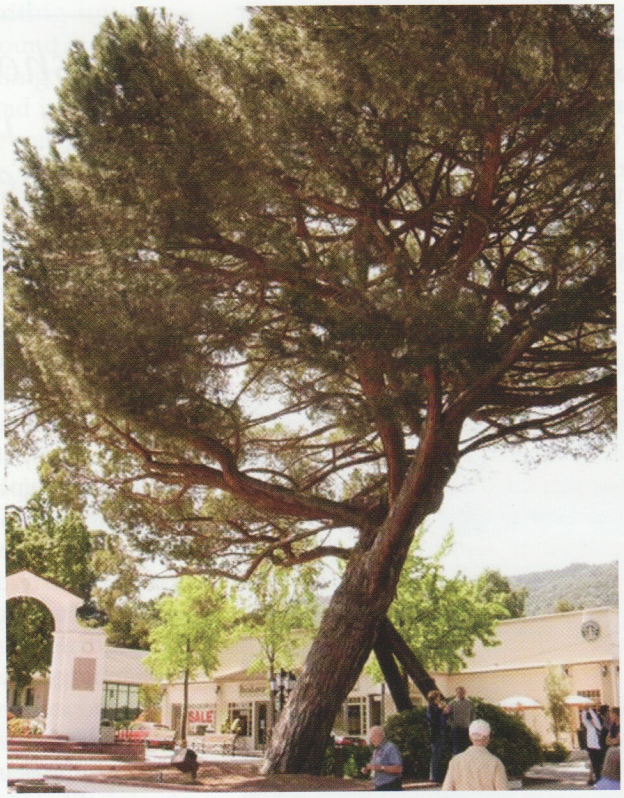

Fig. 7. Lean has been reported as a key factor contributing to root failure of Italian stone pine. Here, large props have been installed to reduce the failure potential of this leaning specimen. *Photo: T. Kipping.*

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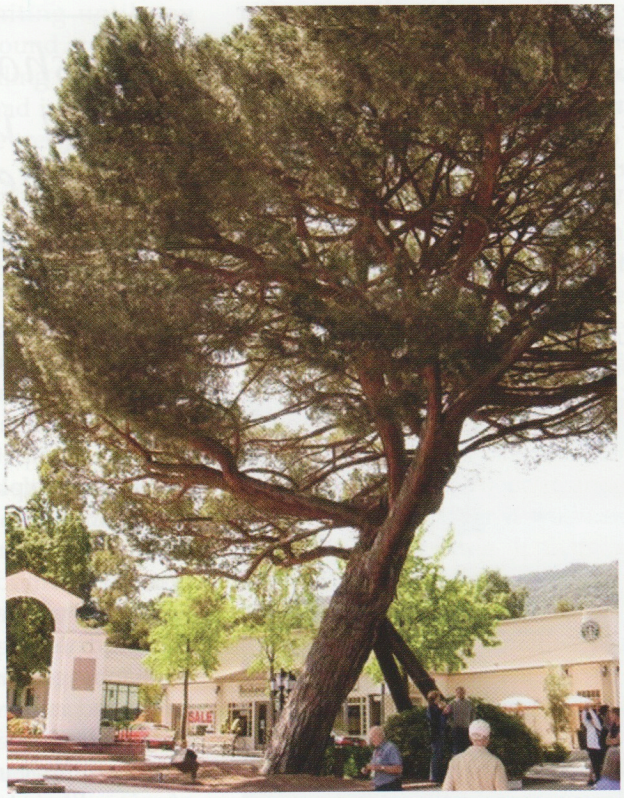

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