FRANK LLOYD WRIGHT'S FALLINGWATER

[1] Designed in 1935 and completed in 1939, Fallingwater is recognized as one of the most unique houses ever built in America. It is not only one of architect Frank Lloyd Wright's most distinctive accomplishments but is also a monument to Wright's concept of organic architecture – harmonizing man with nature so effectively, that the structure and its surrounding environment become a single, unified composition.

[2] The house looms over a waterfall on Bear Run in northwest Pennsylvania. Following the natural pattern established by the stream's rocky ledges, the structure is positioned over the falls in a series of cantilevered concrete "trays" anchored to sandstone masonry walls. Although the structure rises more than 30 feet above the falls, the predominance of its horizontal lines makes the house appear to be hovering, thus creating the sheltering effect. Two outdoor terraces extending prominently from the living room and master bedroom comprise almost as much floor space as the interior of the house.

[3] Fallingwater was built by the Kaufmann family, owners of the Kaufmann department store enterprise in nearby Pittsburgh. The family used the home as a weekend and vacation dwelling until 1963, when the property was donated to the Western Pennsylvania Conservancy.

[4] Wright planned each facet of Fallingwater to blend with the natural surroundings. A series of four large bolsters built into a natural sandstone ledge comprise the structure's foundation. Three of these bolsters are made of reinforced concrete, and one is made of stone masonry. Three-foot wide girders daringly cantilever outward from the bolsters approximately 15 feet over the stream. These girders are the primary support for the main level terrace. Concrete joists (four inches wide) spaced at four feet on center span

the girders and support wooden planking. Stone flooring rests on the planking. One of the home's signature features is the soffit slab that is both a structural and architectural asset. This slab works integrally with the girders as a load-carrying T-beam, while providing an aesthetically pleasing smooth finish on the structure's underside.

[5] The master bedroom terrace cantilevers approximately six feet farther out than the main level terrace. Four vertical structural steel T-shaped members span upward from the main level to support the master terrace cantilever. Interestingly, these members are also used as window mullions. This was another strategic move by Wright to seamlessly blend structural elements with architecture.

The problem

[6] Bar reinforcement is generally placed in the top of cantilever members to carry tension stresses created by dead and live loads. Such loads at the master and main terraces include stone flooring, furniture, people, and snow. While the cantilever girders at the main level contain sixteen one-inch-square rebars each, engineers found that the reinforcement was inadequate for the design loads. This deficiency has caused both terraces to sag downward towards the stream.

[7] A review of historical deflection data indicated that the vertical movement was active – and progressively worsening. Cantilever deflections of up to seven inches over the 15-foot cantilevers caused tension cracks to appear at the parapet walls at the master terrace. Left unattended, these problems might have eventually caused the structure to fall into the stream below. By the time the house celebrated its 50th anniversary in 1989, growing concerns about the structural integrity of the house – especially deflection and sagging of the cantilevered terraces – led to a comprehensive analysis of the structural deterioration using nondestructive testing methods.

[8] Until the 1990s, tension cracks were cosmetically patched without addressing the underlying structural issues. Cracks reappeared in the patched areas as the terraces continued to deflect. In engineering studies, it was discovered that the master bedroom terrace could not function as an independent cantilever, and was transferring its load to the living room level below. The master terrace is propped up by four steel mullions from the main level. Calculations indicated that this additional load increased stresses at the main terrace to critical levels. Restorative action was recommended to avoid the eventual collapse of the structure.

Repair Procedures

[9] The Fallingwater renovation plan calls for both strengthening and concrete repair. At the main terrace level, strengthening will include bonded post-tension tendons parallel to the cantilever girders, and unbonded tendons in the transverse direction. The tendons start at points near the bottom of the existing concrete members and gradually rise up to the top of the existing beams at midspan. This will create a lifting effect, or positive bending moment, on the cantilevers when the tendons are stressed.

[10] The strengthening plan also calls for steel channel beams to be bolted to each side of the master level concrete joist directly above the four 'T'-shaped mullions. These channels will ensure that the beam has sufficient strength to achieve the proper transfer of forces from the living room to the master terrace. Like the post-tension cables at the main level, these channels will be hidden from view in the floor cavity.

[11] Another aspect of the repair procedures will involve repair and strengthening of the master level parapet walls. These walls have experienced significant cracking due to the cantilever deflections. The plan calls for three 14-foot-long FRP (fiber-reinforced polymer) bars to be epoxy-grouted into narrow grooves cut into each of two parapet walls. This procedure will keep existing cracks from reopening. In addition to the new bar reinforcement, a significant amount of epoxy crack injection repair will be performed by VSL on the parapet walls.

[12] Once the post-tensioning strands, FRP rods, and steel channels are installed, the concrete will be patched and finished to match existing surfaces, thus leaving no visible trace of the work performed.

From: Structural Group, *Fallingwater project background,* 2003, (http://wwwstructural.net/Fallingwater/fallingwater_bkgd.html).

GLOSSARY

unique = eccezionale, unico
accomplishment = riuscita, realizzazione
to loom = apparire, profilarsi all'improvviso
waterfall = cascata
tray = ripiano
sandstone = arenaria
masonry = muratura
hovering = sospeso
to shelter = riparare, coprire
enterprise = impresa
to blend with = armonizzarsi
bolster = piano d'appoggio, mensola
ledge = cornice, ripiano
reinforced concrete = cemento armato
stone masonry = muratura in pietra

girder = trave, trave maestra
joist = travetto, travicello, travello, putrella
planking = tavolato, assito
soffit slab = lastrone dell'intradosso
finish = finitura
steel = acciaio
mullion = colonnina (di finestre)
seamlessly = senza giunti
to carry tension stress = reggere gli sforzi di tensione
dead load = carico fisso
live load = carico accidentale, carico di traffico
rebar = ferri, staffe
design load = carico teorico
to sag downward = abbassarsi, cedere
worsening = peggioramento
tension cracks = fessure dovute alla tensione
patched = aggiustato, rappezzato
to address = affrontare
to strengthen = reinforzare
bonded = collegato, connesso
post-tension tendon = controventature
at midspan = a metà
to be bolted to = da fissarsi a
to call for = richiedere
epoxy-grouted = con rivestimento epossidico
groove = scanalatura
to match = accompagnare

NOTES

In English the suffix *-ing* can be added to nouns and verbs to create uncountable nouns, e.g. *house* ('casa') → *housing* ('alloggio'), *floor* ('pavimento') → *flooring* ('pavimentazione').
The floor was paved in stone.
Stone flooring rests on the planking.

Farther and *further* are both comparative forms of 'far'. When talking about distance both forms are possible, but when talking about the extent or degree of something only *further* is possible.
Compare:
They walked on to the farther/further side of the village.
He is waiting for further instructions.

COMPREHENSION

Exercise 5
Which paragraph in the reading passage:

1. describes the nature of organic architecture? ☐
2. describes the original use of Fallingwater? ☐
3. gives statistic information that shows the tension cracks were gradually becoming worse? ☐

4. explains why the house seems to be hovering? ☐
5. describes the house foundations? ☐
6. explains why the terraces now sag downwards? ☐
7. describes the planned renovation programme for the main terrace level? ☐
8. describes the future repair procedures of the walls? ☐

VOCABULARY

Exercise 6
Which of the following is not...

1. a material?
   a. midspan b. sandstone c. reinforced concrete
2. a structural element?
   a. soffit slab b. ledge c. facet
3. mentioned in the passage?
   a. master bedroom b. attic c. terrace
4. a supporting element of the house?
   a. wooden planking b. bolster c. girder
5. a structural fault of Fallingwater?
   a. deflection b. hovering c. sagging

Exercise 7
Fallingwater has been found to have serious construction faults. Read the following passage and complete the following sentences with one of the words below.

flagstone	tension cracks	strengthening	cantilevering
design loads	sagging	slab	ledge

Historians have often claimed that the design of Fallingwater with its smooth rectangular concrete planes interlocking and 1. _____ out into space was Wright's "answer" to the international Style of Architecture. The plan of Fallingwater emphasises the underlying order of the series of parallel walls and piers standing on the rock 2. _____ perpendicular to the stream on its north shore, which support the main volume of the house. Wright's associates calculated the structural loads in the revolutionary, thin-shell reinforced, hollow columns, which held five times their 3. _____ . The 4. _____ floor was supported by integral upturned beams. This ingenious design placed the flat 5. _____ on the

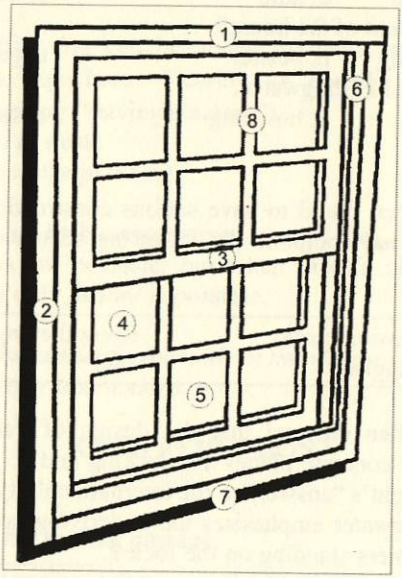
bottom, forming the ceiling of the space below. The miscalculation of the contractor and engineer was using twice as much steel as actually required in Wright's plan. This resulted in both terraces 6. _____ downwards. Another consequence was the appearance of 7. _____ _____ . Current renovation plans require both 8._____ _____ and concrete repairs.

FURTHER VOCABULARY

Exercise 8

In accordance with Wright's philosophy of "organic architecture", the nature surrounding Fallingwater is reflected inside the house with its stone floors, wooden furniture and the numerous windows. Label the diagram of the window below using the following words.

grille	sill	sash	pane
glazing	frame	jamb	head



1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____