The Clay Research Group

RESEARCH AREAS

Climate Change ◆ Data Analysis ◆ Electrical Resistivity Tomography
Time Domain Reflectometry ◆ BioSciences ◆ Ground Movement
Soil Testing Techniques ◆ Telemetry ◆ Numerical Modelling
Ground Remediation Techniques ◆ Risk Analysis
Mapping ◆ Software Analysis Tools
Artificial Intelligence

March 2017
Edition 142

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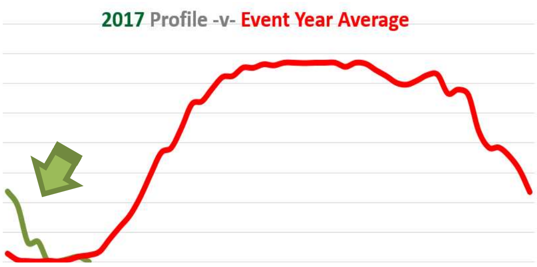
Issue 142, March, 2017

Soil Moisture Deficit

Soil is at equilibrium capacity for the start of 2017, and far too early to predict summer claim numbers.



Soil Moisture Deficit plot showing soil drying (green) compared with average for event years (red). Data supplied by the Met Office for Tile 161, Medium AWC, grass cover.

Calm down …

This month's edition includes an article from Clive Richardson that first appeared in the Architects' Journal, September 2000, reproduced with their consent.

Clive discusses the significance of structural damage to domestic buildings and whether perhaps homeowners and engineers' perceptions/expectations need to change.

Rising Sap

Dr. Jon Heuch of Duramen Consulting explains the physiology behind the report in the October 2016 edition of the newsletter (No. 137) describing the work being undertaken by researchers at the Laboratory of Plant Ecology, Ghent University, Belgium relating to sap flow and changes in trunk diameter.

Subsidence? Or maintenance?

Clive Richardson's article re-ignites the debate about levels of damage. Are minor cracks that re-appear every five years or so as a result of clay shrinkage really subsidence? Or should they be treated as routine maintenance?

How does the homeowner hope to sell a property with the caveat "you may have to fill some small cracks in the living room every now again, particularly if it's a dry summer. It's the neighbour's tree but don't worry". Would the purchaser get insurance? Could they get a mortgage?

Has providing insurance cover created the problem? Are house prices the driver, rather than crack widths?

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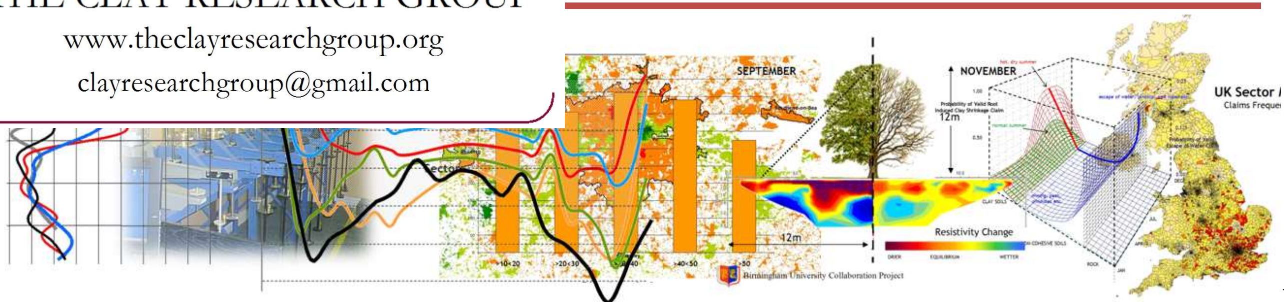
www.theclayresearchgroup.org
clayresearchgroup@gmail.com



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Landslip at Filey, Yorkshire

Right, the before and after pictures tell the story.

Movement had been ongoing for some time as the cliff face eroded.

Further minor damage was reported in 2015, and catastrophe struck in 2016 when part of the bungalow was lost to the eroding cliff face.

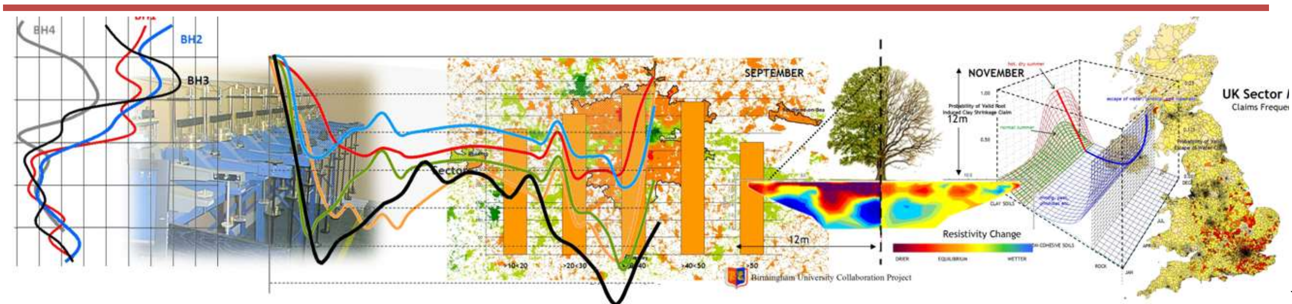
The homeowners took a philosophical view. They had enjoyed marvellous views and recognised that at some stage the loss was inevitable.

So near … and yet so far

Rainwater downpipe discharging directly into the ground. A non-cohesive soil supporting the foundations.

What could possibly go wrong? Yes, water discharging from the downpipe softened and eroded the underlying soil, resulting in minor damage to the corner of the house.

Frustratingly, a water storage butt is nearby.



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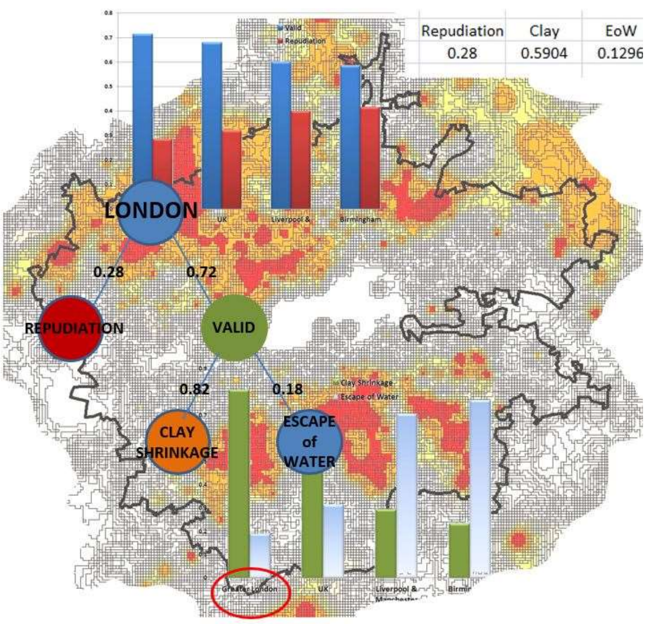
Digital Analysis and Risk Mapping

Understanding the probability of a claim being valid and the likely operating peril is central to developing triage applications that improve claims handling by directing resources quickly and efficiently, shortening lifecycle and cost. On this and the following page data analysis is applied to illustrate how this might be achieved.

Mapping the data gives a clear visual indication of risk and allows us to match risk with causation – i.e. geology. See edition 126, November 2015.

The exercise identifies differences and similarities across four cities. London, Birmingham, Liverpool and Manchester.



London, mapping claim frequency distribution and likely operating peril.

Left, data and map of subsidence risk for London, showing the frequency distribution of claims, the likely operating peril and the probability of whether those claims are valid or declined.

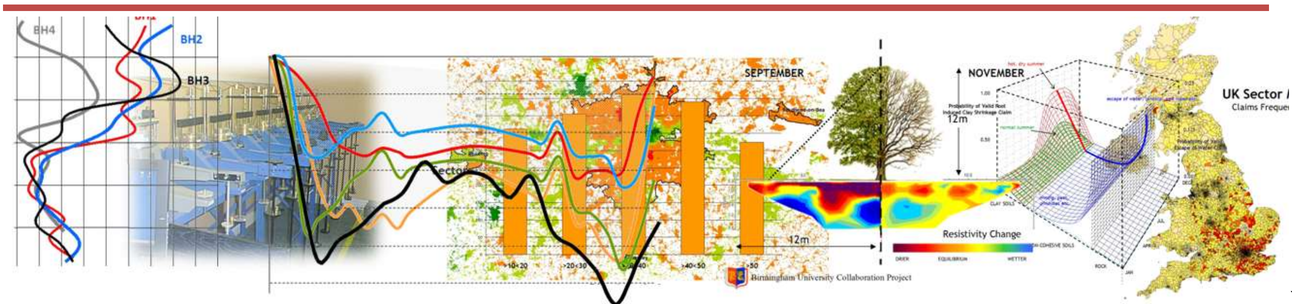
From the unsorted claim sample (i.e. not sorted by season or geology), the chances of a claim being valid over the year are quite high at 72%.

Across all geologies, the probability of a valid claim being due to clay shrinkage is nearly 82%.

This reflects the high density of housing on the clay series.

The primary risk in London is driven by the outcropping London clay. Although this analysis doesn't take account of the season, there are sectors where valid claims reach 90% of notifications, and by far the great majority in that instance will be root induced clay shrinkage.

In contrast, Birmingham, Liverpool and Manchester (see following page) have as their dominant peril escape of water claims, associated with the predominantly non-cohesive soils.



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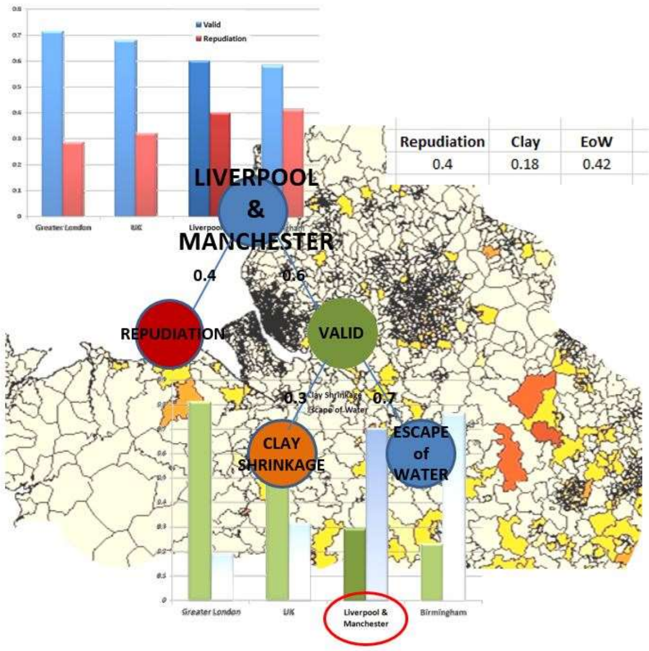


Liverpool and Manchester combined, mapping claim frequency distribution and likely operating peril.

Liverpool and Manchester

Left, the combined values for **Liverpool** and **Manchester**. The chances of a claim being valid are around 60%. This is less than London (72%) and similar to Birmingham (58%).

The dominant peril is an escape of water from the drainage system or, less likely, a water service pipe. Clay shrinkage related claims account for 30% of valid claims, and leaking drains etc., the balance of 70%.

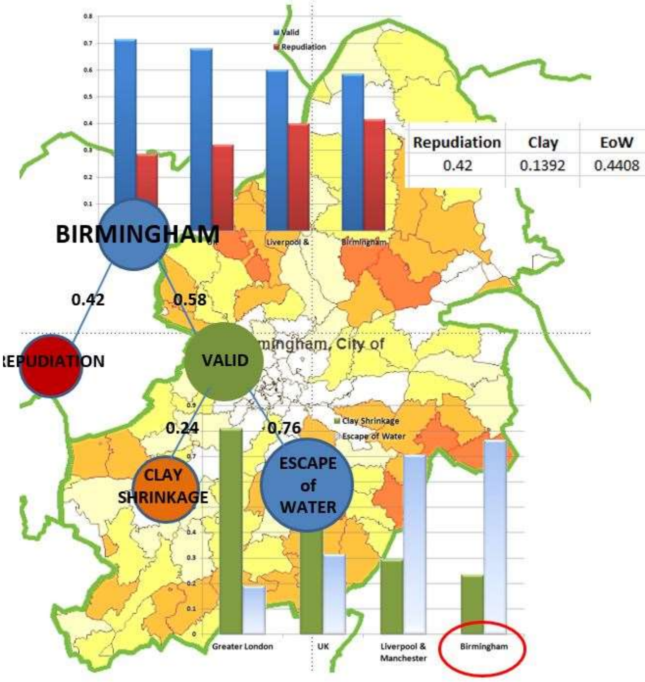
Of all claims, 18% are related to clay shrinkage and 42% escape of water.

For **Birmingham** (right), the chances of a claim being valid are slightly less, at 58%.

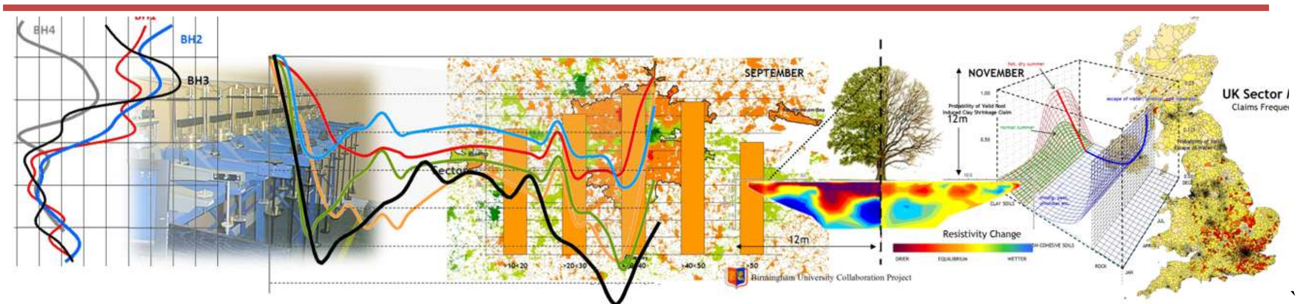
The dominant peril is an escape of water from the drainage system or less likely, a water service pipe. Clay shrinkage accounts for 24% of valid claims, and leaking drains etc., the balance of 76%.

The table (top right of the image in all instances) resolves the distribution as percentages of the whole sample.

Of all claims (declined and valid), 14% are related to clay shrinkage (predominantly associated with the smectite rich clays to the south east of the city) and 44% escape of water.



Birmingham, mapping claim frequency distribution and likely operating peril.



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Keep Calm and Carry on Wallpapering

Clive Richardson

Clive Richardson is a structural engineer, technical director of AECOM consulting engineers, and technical secretary of the ICE/IStructE building conservation panel. E-mailclive.richardson@aecom.com

Not all cracks are caused by subsidence

In the immediate post-war years, when we were grateful for any accommodation which had survived the Blitz, attitudes to odd cracks were relaxed. While redecorating, my father would summon us to see finger wide cracks discovered beneath the wallpaper, before ceremoniously plugging them with newspaper and filler. No panic attacks for him, whereas nowadays I am increasingly called out to pronounce upon hair-line plaster cracks dramatised by white emulsion paint.

Expectations of building performance have become unreasonably high. The great forces of nature break down mountains eventually, so we must not assume that a mere building will last indefinitely. Regular maintenance and occasional structural intervention are essential to slow the process of deterioration and to extend the life of a structure. But it is time for reactions to be tempered by considering the issues.

This article deals with structural movement, relating to those parts of the building fabric which confer significant strength, stability and integrity. Roof carcassing, floors, walls, frameworks, and foundations form the principal structural elements. Non-structural fabric, such as plaster, render, windows and doors, help stiffen a structure but their contribution is not to be relied upon in a significant way.

Subsidence, heave, sway, bouncy floors, bulging walls, cracks, expansion and contraction are all forms of structural movement.

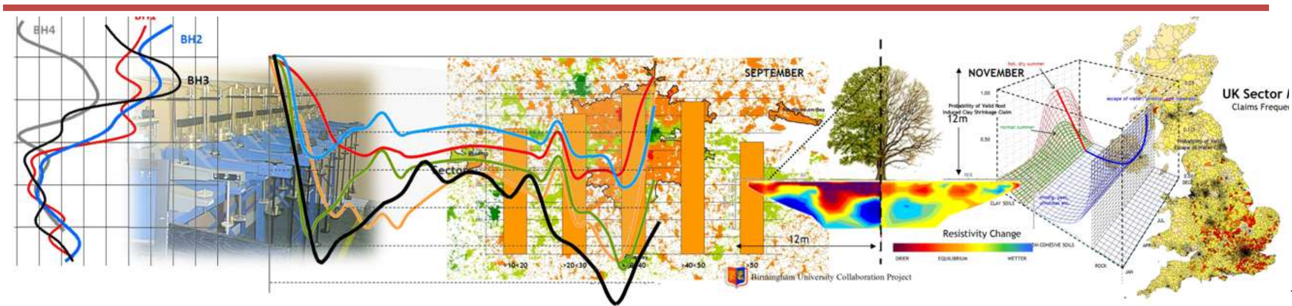
Such movement occurs all the time and usually its magnitude is so small it passes unnoticed. We need be concerned only when movement threatens the use or safety of the structure.

New structures are designed so that strains are kept within reasonable limits. Safety factors cater for variations in materials, design or construction inaccuracies, and random/accidental forces.

In historic structures, detrimental movement results from inadequate design and construction, decay and ill-considered alterations.

Early historic structures succeeded because safety factors were incorporated by experience rather than calculation. Nevertheless, in medieval structures it is common to find secondary floor joists larger than they need be, while primary beams are undersized and sag excessively.

Apart from this, and some more singular problems, it is perhaps surprising that inadequate strength is generally not more of a problem.



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From the start of the Industrial Revolution, the increasing involvement of engineers ensured more adequate sizing of structural members. Exceptions include domestic buildings with timber floors over-loaded by subsequent office use.

The battle can largely be won by giving a building a good roof, and ensuring that driving rain is thrown clear of the building by generous drips, eaves, over-sailing copings, and cills; and by preventing rising damp with a damp-proof course.

Table 1: THERMAL AND MOISTURE MOVEMENT OF MASONRY (MM/M LENGTH OF WALL)

	FIRED CLAY BRICKWORK	SAND-LIME BRICKWORK	CONCRETE BLOCKWORK	PORTLAND STONE
Permanent moisture movement	0.6 (expansion)	-0.25 (contraction)	-0.6 (contraction)	zero
Reversible moisture movement	+/-0.2	+/-0.3	+/-0.3	+/-0.1
Reversible thermal movement	+/-0.15	+/-0.3	+/-0.3	+/-0.1

NOTE: Values given are average. See BRE Digest 228.
Values vary depending on exposure, restraint, and pre-compression.
Movement is given 30degC temperature range.
Portland stone is the 'Rolls Royce' of masonry materials for dimensional stability.

The vast majority of the nation's structures are low-rise unframed buildings, where the individual components are predominantly held together by friction and gravity.

Most such structures (speculative Georgian and Victorian housing, for example) have outperformed the expectations of their constructors without the involvement of engineers and despite the ravages of two world wars.

However, as buildings relax and become frail with age, the single kindest way of increasing their longevity is normally to tie them together. Conversely the lack of continuity leaves the structures vulnerable to disproportionate damage.

Material decay

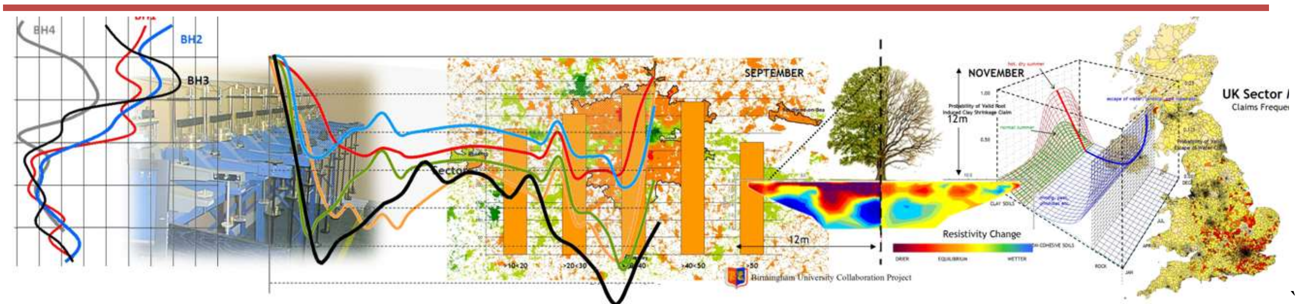
Water is the principal agency affecting the decay of most structural materials, causing: frost damage of masonry: rot of timber: and rusting of iron and steel.

Stone, brick, and concrete expand and contract and the resultant strain must be accommodated by the structure, or permanent deformations and cracks will occur.

If movement is cyclical, then such cracks may grow due to the 'ratchet' effect of debris in the cracks preventing full closure.

In most UK structures the principal loadbearing element is masonry. Different types of masonry move at different rates and sometimes in opposing directions. This can give rise to differential movement and distortion (see sketch 1).

Fortunately, most walls constructed before 1914 were set in lime mortar, which can accommodate considerable amounts of creep (continual strain under constant stress) without cracking, whereas more modern walls set in cement mortar require more frequent provision of movement joints (see sketch 2).



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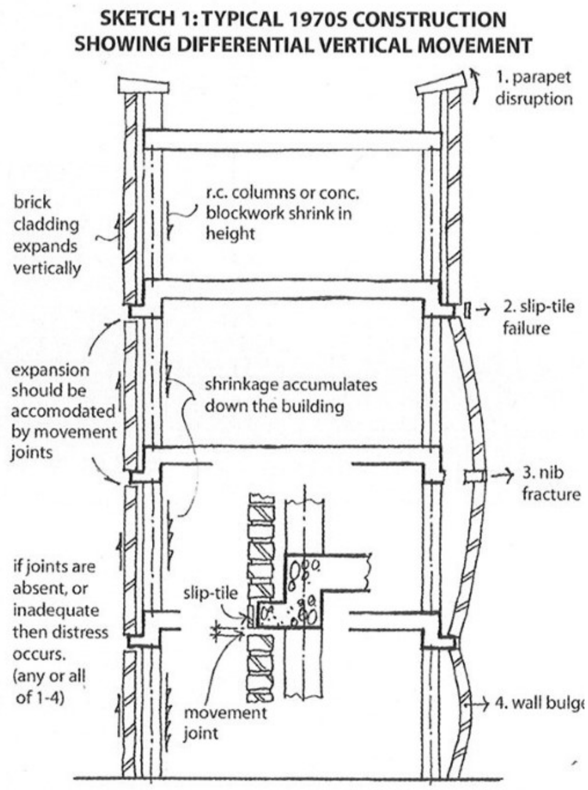

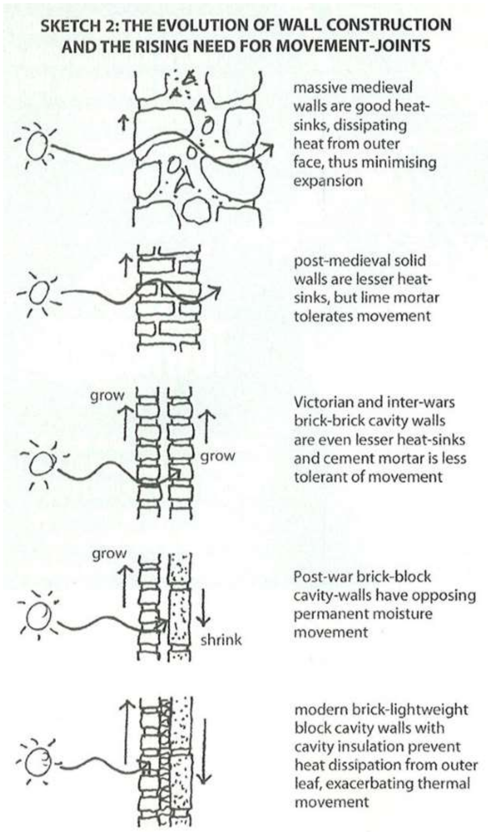

Subsoil and foundations

In good ground, corbelling the base of walls – to provide a wider distribution of the load on the soil to reduce settlement – continued until the First World War, latterly with a shallow strip of concrete first cast into the trench, about 500mm below ground.

Movement of shallow spread foundations is commonly caused by normal constructional settlement, mining, leaking drains, shrinkable clay, tree-roots, changes of water-table, tunnelling and additional loads (see sketch 3 on following page).

Flexible historic buildings are often better able to cope with movement than modern rigid structures, thanks to the prevalence of soft lime mortar, massive walls, timber frames, arches, and vaulted construction.

Modern structures with slender walls set in hard cement mortar with brittle plaster and no cornices, show every crack.

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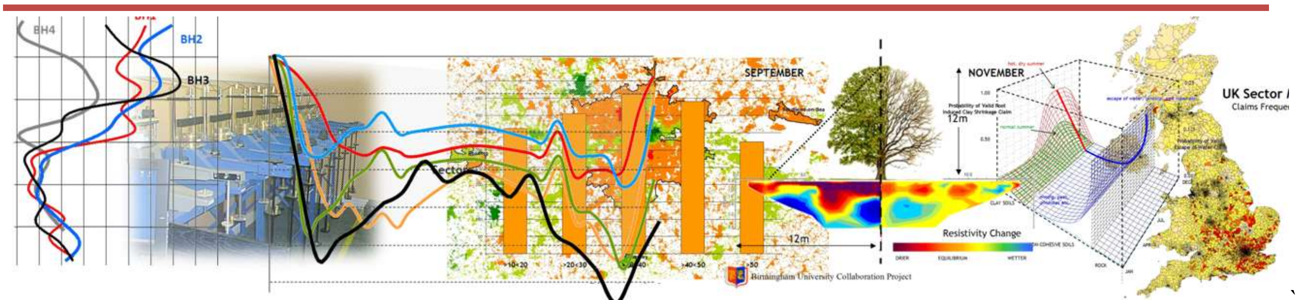
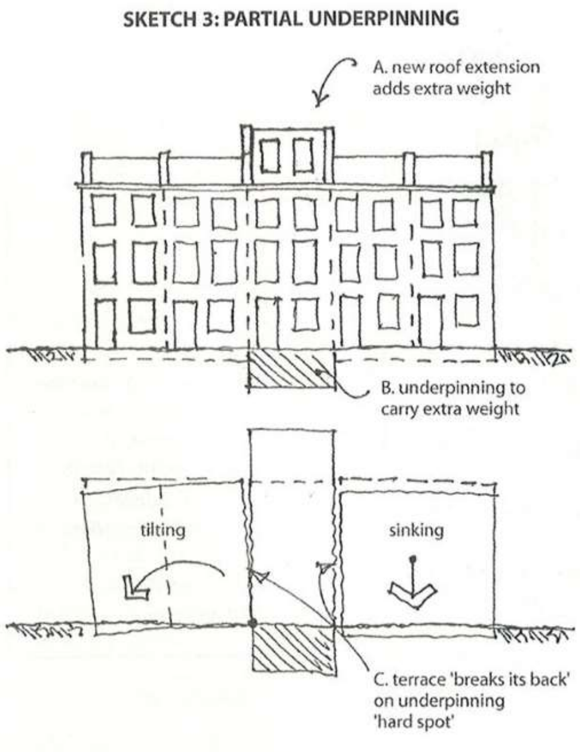




Overall instability

A lack of bracing can ultimately lead to collapse.

Many a medieval church, for example, has had a gable end rebuilt following movement of its unbraced roof: this was prevented in more elaborate construction by diagonal wind-braces which were inserted in the plane of the rafters.

Notched floor joists for services, doorways cut through trussed partitions, partly removed chimney breasts and overloaded floors are the most popular abuses of buildings. Many such alterations become obscured over the years, and it is only investigative work that will uncover the cause of the distortion (see sketch 4 – following page).

Random forces and accidental damage are unpredictable. Explosions cause high pressures and suctions for very short durations. These dynamic loads cause overload, stress-reversal and dynamic rebound of structural elements. Ductile materials such as steel and reinforced concrete perform better than brittle materials such as timber, masonry and glass.

Fortunately, modern framed buildings have good natural resistance to explosions.

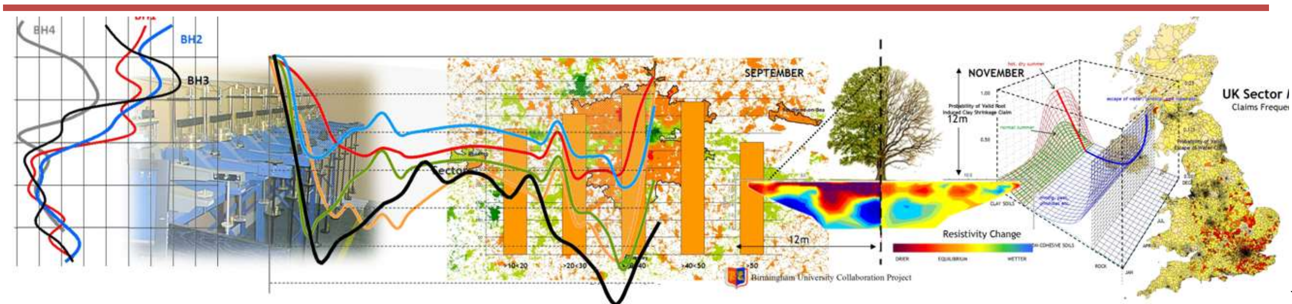
Assessment of stability

Against this background of potential causes of movement, it is hardly surprising that buildings seldom perform perfectly, and rarely acquire true stability. But is this important?

A stable structure is a system of pent-up forces and forces never sleep. They will always take advantage of any weakness to cause movement. The odd distortion can be part of the charm, particularly for a historic structure.

Although engineers may be unnecessary for minor symptoms of movement, the need for equilibrium must be borne firmly in mind when exercising the '100-year rule'. This says that if a building has stood for a century why should it not stand for another year or two, and subsequent increments to infinity?

While nothing may have apparently changed during the period of observation, structural fabric gradually degrades due to weather, thermal and moisture cycling and dynamic loads.



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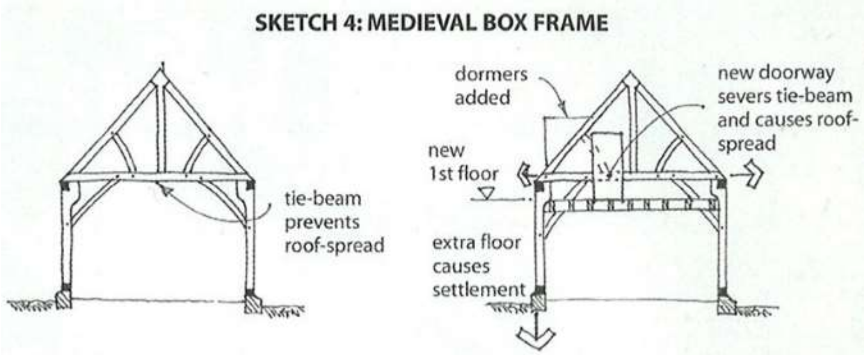
For a relatively modest structure such as a house, no action may be considered necessary unless the structure is likely to fail within a period of perhaps five years.



For a cathedral, a much larger safety margin would be necessary, of perhaps 50 years due to its scale and the high cost involved in carrying out major works.

Expectations for the duration of a repair may also vary (see table 2 - below).

An engineering assessment of the seriousness of any particular symptom of structural distress is not just by calculation, but also through an understanding based on practical experience of the performance of structures and the intangible contribution of the non-structural fabric, such as the stiffening effect of horse-hair in old plaster, or modern sheet flooring.

Table 2: HOW LONG SHOULD BUILDINGS LAST?
Depending upon the financial, technical or material resources availabe, new structures or structural repairs may be designed to be serviceable for a specified minimum period. This might be:
● between cyclical inspections;
● a loan repayment period;
● full repairing and insuring lease duration;
● 30 years (housing corporation rehabilitation cycle);
● 60 years (housing corporation new build);
● 80-100 years (a lifetime - the layman's expectation); or
● ad infinitum (listed buildings and scheduled ancient monuments).

The Building Research Establishment offers some guidance on the seriousness of crack widths, but this must be used circumspectly.

Cracks should be examined to determine their cause, not rigidly filled in to see if they reappear, as this may restrict cyclical movement causing the problem to escalate.

In so doing, structures can tiptoe towards disaster, and we must therefore by quite sure that a building which may be showing signs of previous movement has indeed acquired a new stage of equilibrium and is not having its margins of safety eroded perilously close to failure.

Structural movement is serious when the safety margins of strength, stability, or integrity have been significantly eroded, or the movement is progressively leading to failure within a specified period.

Careful examination can reveal the direction of movement, and whether movement is ongoing.

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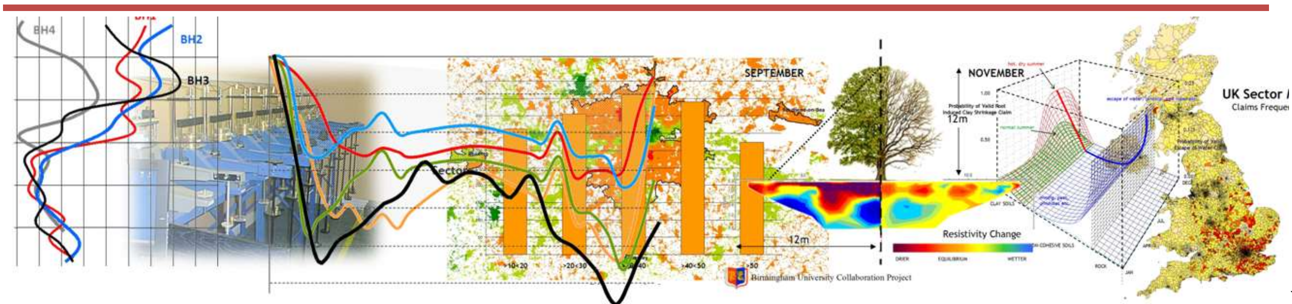


If the probable cause of the structural movement is still unclear or if the movement is suspected to be progressive, then movement monitoring is warranted (see table 3 below).

Monitors are aids to diagnosis and prognosis, not a substitute to understanding structures.

Table 3: MOVEMENT MONITORING EQUIPMENT

NATURE OF MOVEMENT	APPROPRIATE EQUIPMENT	EQUIPMENT ACCURACY +/-mm
Level divergence	Water level	2.5
	Spirit level	2
	Dumpy level	1 - 2
	Precise level (bar coded)	0.2 - 0.4
	Electrolevel	0.01 degree
Verticality divergence	Giraffe	5
	Plumb line	2 - 5
	Infra-red EDM	
	(holographic prism)	1 - 3
Strains and cracks	Tape extensometer	1 - 2
	Perspex tell-tales	0.5
	Vernier markers	0.1
	Transducers	0.01

Hopefully the days have long gone when well-intentioned but misguided persons stuck glass tell-tales across cracks with disfiguring blobs of resin, in the vain hope that their demise would explain the cause. Mostly the glass would come unstuck, or schoolboys like me would break the glass for fun.

The arsenal of equipment available today is vandal-resistant, and when used wisely, gives meaningful results.

Once the causes have become clear, it is straightforward to eliminate them, and also make repairs.

Conclusions

Structural movement need not really be a problem when considered rationally. Although structures rarely acquire true stability, cracks and bulges are not always serious, and crack monitoring is not automatically necessary.

What needs to change is people's expectations.

The Victorians had the right idea; cornices to conceal movement between ceiling and wall junctions, woodwork painted chocolate brown to camouflage joint shrinkage, and stretchy lincrusta wallpaper to obscure random cracks.

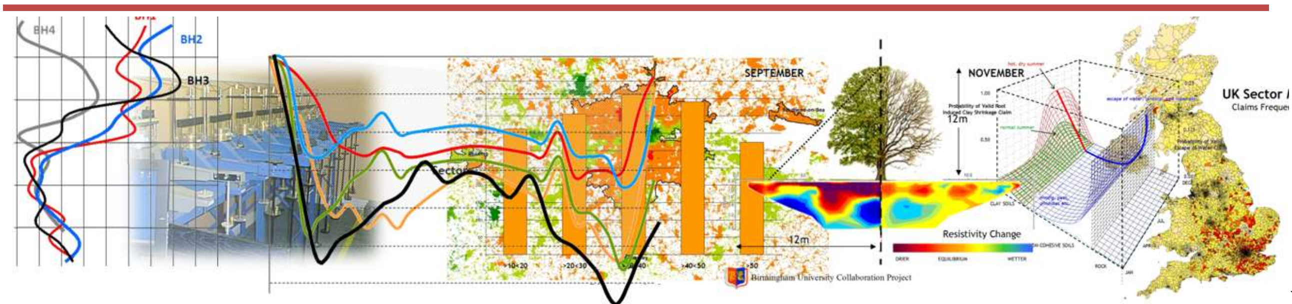
NOTE: This article has been reproduced with the consent of The Architects' Journal where it appeared in September 2000, entitled "Moving Structures". The message remains just as true today that not all cracks are due to subsidence.

BRE Digest 352

Clive's advice fits in well with guidance provided in BRE Digest 352, where it states, "the degree of movement and consequent cracking that causes concern to homeowners is rarely of structural significance".

At the time the Digest was published (1990) it reported "as many as 14,000 families will experience the anxiety and disruption of the underpinning process".

See edition 117 of the newsletter for a review of the Digest.



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Rising Sap and Fluctuating Trunk Diameter

An explanation from Dr. Jon Heuch, Duramen Consulting

https://treewatch.net/thunen-institute-forest-ecoystems/

An article in edition 137 of the newsletter reported on work being undertaken at the Laboratory of Plant Ecology, Ghent University, Belgium[1] recording sap flow and changes in trunk diameter both diurnally and annually. The team recorded an increase in trunk diameter commencing around 6pm each day, and then shrinking around 6am the following morning. The expansion cycle is an evening process. In contrast, sap starts rising at 6am and reduces towards mid-day.

Over a longer term, the cycle is repeated with the trunk gradually increasing in diameter. Researchers recorded an increase in trunk diameter of around 6mm.

We were alerted to the study by Jon Heuch and asked him if he was able to provide an explanation of their findings. Jon explains …

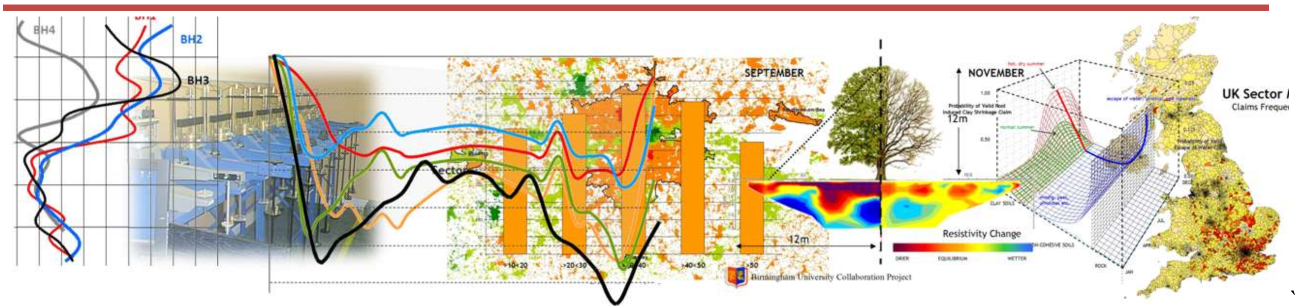
"Loss of water from the leaves doesn't lead to instantaneous uptake of water in the roots. The easiest part of the tree to monitor is around chest height on the main stem so that is where the monitoring equipment tends to go, or slightly higher to prevent looting of expensive equipment.

At equilibrium we imagine roots, stem and leaves all have adequate water content without any excessive stresses or strains; in the absence of drought this is likely to occur at or just before dawn. As sun rises the tree requires carbon dioxide from the atmosphere and so opens the stomata on the leaves; water promptly is lost from the leaves leading to a suction effect from all the leaves onto the main "storage" area i.e. the main conduits for water – the xylem.

The suction leads to the xylem losing water and thus overall the stem shrinks slightly. That suction is transferred down to the roots and the roots slowly suck up water and nutrients.

The suction from the leaves subsides in later afternoon and as darkness starts but the roots keep "pumping" to rectify the loss encountered in the xylem. As a result, the xylem heads toward equilibrium during darkness …. the stem slowly swells."

[1] Novick, K., et al., "The increasing importance of atmospheric demand for ecosystem water and carbon fluxes." Nature Climate Change, 2016



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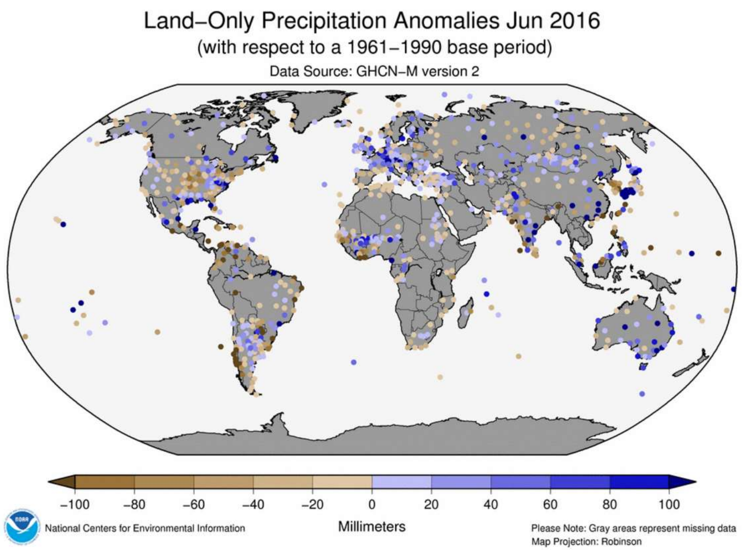
Warming Globe

NOAA have published a list of the top 12 years in terms of global warming when compared with the average for the period from 1880 – 2016. Below are the top 5 years. Three years are tied in 10th place - 2003, 2006 and 2007.

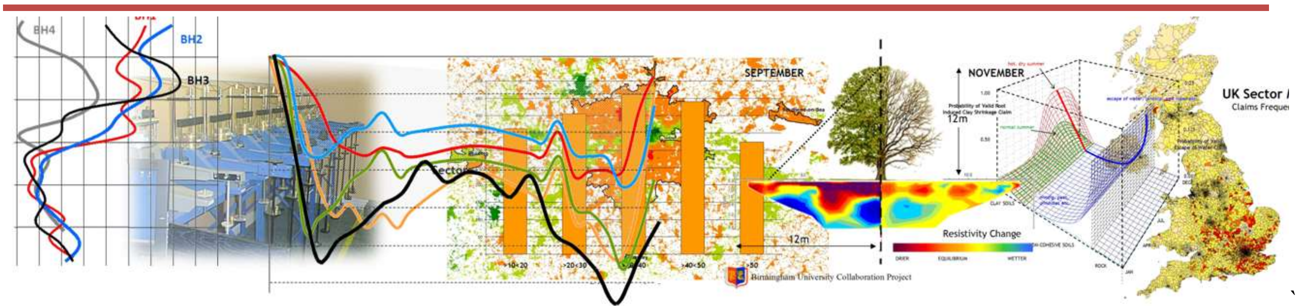
RANK	YEAR	ANOMALY (Deg C)
1	2016	0.94
2	2015	0.9
3	2014	0.74
4	2010	0.7
5	2013	0.67

Go to https://www.ncdc.noaa.gov/sotc/global/201613#gtemp
The last three years show consecutive periods of warming, along with the anomaly value from the 1880 – 2016 period in degrees Centigrade.

The Met Office reported that June of 2016 was particularly wet with 139% times the rainfall compared with the 1981-2010 average. Below, a map of global rainfall for June 2016 showing a concentration of wet weather covering the UK.



https://www.ncdc.noaa.gov/temp-and-precip/global-maps/201606?products[]=map-prcp#global-maps-select



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In the (arboricultural) news…

Most wood energy schemes are a disaster for climate change

Using wood pellets to generate low-carbon electricity is a flawed policy that is speeding up, not slowing down, climate warming. That's according to a new study which says wood is not carbon neutral and emissions from pellets are higher than coal.

Subsidies for biomass should be immediately reviewed, the author says. Energy from trees has become a critical part of the renewable supply in many countries including the UK.

http://www.bbc.co.uk/news/science-environment- 39053678

Tree surgeon dies after chainsaw kicks back into neck

"31 year old Gregery Bulbec died while trimming a tree on private property in London when the saw kicked back and hit him in the neck. He was left dangling 21 feet in the air by his climbing harness as co-workers quickly got a ladder and tried to bring him down out of the tree. Despite the best efforts of the co-workers, Bulbec died at the scene. He was a Romanian worker employed by Aralia Tree Service."

Man pulled head first into chipper but is expected to survive

"A man in his 20s was pulled head first into a wood chipper when his harness tangled in branches.

Luckily his foot tripped the safety bar before his head reached the chipper blade. The arborist was wearing a helmet during the time of the accident which firefighters say saved his life. He was taken to Peace Health Sacred Heart Medical Center at RiverBend in Springfield, Oregon. The victim suffered trauma to the back of his head and a broken leg but it expected to survive."

http://dripline.net/man-pulled- head-first- into-chipper- but-is- expected-to- survive/