STEEL FOCUS #8 STRUCTURAL STEELWORK



PLAYING WITH GRAVITY

The Isaac Newton Academy in Ilford has a new sports hall – but how did Feilden Clegg Bradley make it hover?

AN OFFICE FIT FOR A QUEEN

3DReid's beehive-inspired Co-op HQ uses more than 2,000 tonnes of structural steel to create column-free spaces with a real buzz

HOW TO BE BETTER THAN GOOD

With Breeam ratings more important than ever, new research reveals the most cost-effective ways of hitting the highest scores

STEEL FOCUS ISAAC NEWTON ACADEMY FRIDAY 01/02/2013 10

Beam meup

Feilden Clegg Bradley Studios overcame space restrictions for a new east London secondary school by constructing its sports facility over an existing council car park

Text by Pamela Buxton Photos by Adam Scott

Clegg Bradley Studios' steel-framed design for the Isaac Newton London, a 1,250-pupil school spe- ridors and provide natural light was also partly a response to the cialising in maths and music. The narrow site was tightly con-

strained by a cemetery, terraced housing and a Redbridge Council- the building line suggested in the volumes," explains studio owned car park, which had to remain operational during and after construction. The brief specified 11,700sq m of accommodation, architects to provide the other commodation; and the other, but building high to compensate for the small footprint was not an option because of height restrictions owing to the proximity of the housing. An added complication was the organisation of the school into effectively four separate year stages (key stage 3 A and B; key stage 4; key stage 5), each with its own entrance/reception and outdoor play area.

Faced with the prospect of providing a deep block without the quality of natural light and outdoor spaces they wanted, the architects took the risky step of instead proposing a doubleheight "sports beam", projecting 55.8m out of the main building beyond the school's original site boundaries and over the car park, supported on two-storey steel columns.

"It seemed virtually impossi- 1 Sports beam ble to fit all the accommodation 2 Main school building

oncepts of gravity and within the buildable area with- ing four-storey main block, levity informed Feilden out seriously compromising the permeated with outdoor space plan," says project architect Akos in the form of courtyards and Iuhasz

> "We very much wanted to and views for most spaces, in- work of Isaac Newton. cluding circulation. We could only achieve that by breaching hall above the car park."

roof spaces.

According to the practice, Academy in Ilford, east avoid dark, double-loaded cor- the massing of the two elements "There is the idea of levity

versus gravity with the two guidelines by raising the sports leader/partner Andy Theobald. "One, a heavy brick This strategy allowed the block with most of the acschool facilities in an interlock- a metal box hovering over the



3 Public car park 5 Sports ground

4 Cemetery

says the design team.

an operational car park. The crete flat slab solution.

concrete floor slabs and highly buff brick on the elevations. function as a studio theatre. These brick slips were used

stage 3 inspired by Newton's reflecting telescopes and conceived as translucent light prisms. A further lightwell is introduced over the main entrance through the sports beam.

"We're trying to make it as exciting as possible by intr ducing light in unexpected places," says Theobald.

The new building has a super-insulated, high-performance envelope to reduce energy demands. There is no wet heating system in the teaching spaces. Instead, classroom heating is provided predominantly from the occupants and equipment heat emissions, thanks to the high level of heat reclaim via individual class ventilation "ecoactive" units concealed within classroom bulkheads.

Clad in metallic bronze anodised aluminium, the sports beam has a considerable impact

car park providing the levity." clearly by the architects as tile- cated side by side on the ground These two concepts could also like cladding rather than as a and first floors towards the south suggest that the academy is tectonic element, with the width of the site. Each has classrooms both rooted and aspirational, of the brick bond changing at the perimeter and a common across the elevation to create a space that opens up onto a cen-According to engineer pattern based on the Fibonacci tral courtyard. Positioned next Hardip Bansal, a steel struc- mathematical sequence. Areas to each other, these two gatherture was chosen for construc- of stack bonding with aligned ing spaces can be used together tion speed and because it vertical joints also reference the for joint assemblies if needed. suited the long spans of the stacks of bricks that would have Key stages 4 and 5 are positioned sports beam, as well as the been on the site when it housed on the second and third floors complexities of working over a brickworks in Victorian times. respectively, each with its own The main entrance is posi- breakout space to supplement lack of structural continuity tioned under the sports beam to the limited external play areas. throughout the main building the north of the site, leading to a These external spaces permeate precluded a reinforced con- zone of specialist teaching areas the plan of the main block and with access from each key stage. bring in natural daylight to as This primary structure was These include drama/dinner many rooms as possible. They combined with exposed precast hall, science, art and music. include a key stage 4 court at sec-The dinner hall will have a first- ond floor level, a central court, insulated SIPS panels clad with floor gallery to aid its secondary and to the north an art and design court and a rooftop science Key stage 3 A and B are lo- garden. These are supplemented by two large lightwells in key

Rear elevation of the main school building, showing the sports beam (left) and the main brick-clad school building.



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on the immediately surrounding area and is the only part architects used an overlay of perpendicular aluminium fins on the elevations notched along **PROJECT TEAM** their length to create ring pat- Clients terns, which change with different daylight and viewing an- Borough of Redbridge gles. The underside of the beam Main contractor is clad so that it appears as a Skanska metal box supported 6m above M&E engineer ground level. In all, 1,769sq m Hulley & Kirkwood of metal cladding was used.

"We're trying to transform Skanska Technology a public car park into some- Steelwork contractor thing with more presence and William Hare character, suitable for an im- Landscape architect portant new public building," Grant Associates says Theobald. "It's a potential Project management venue for outdoor activities."

THE SPORTS BEAM

The unusual loads of the 54m-long, projecting sports beam made this a particularly challenging part of the design, with the engineers having to cater for potential rhythmic bouncing taking place in the sports halls while avoiding too many columns protruding into the public space below. The 18.7m-wide beam is supported by five sets of paired columns, spaced 13.5m apart with the exception of the final pair, which is a double to allow for a fire escape staircase at the end of the sports beam. After initially positioning the columns on

the outer edges, the design

The £30 million school opened in September and is of the school visible from the part of the ARK academy group. nearby high street. Drawing "The amount of optimism cominspiration from the concentric ing out of the classrooms is repattern of Newton's rings, the ally inspiring," says Theobald.

ARK Schools and London Structural engineer Gardiner & Theobald

team decided to bring the first four inwards by 2.35m each side to reduce the span to 14m. This provides greater structural rigidity while preserving the visual effect of levity. Central columns were ruled out as they would have made the space on the ground less flexible.

"We wanted to maintain the architectural vision so opted for moving the columns in," says Skanska senior project leader Hardip Bansal. "Just a short reduction in span makes a big difference to structural dynamic response."

Columns are 305mm x 406mm sections and are encased in concrete. They are spanned by 16 beams, each



Bringing as much natural light into the school as possible was a priority.

914mm deep. Walls are effectively giant two-storey trusses At the main block end, a

mezzanine administration floor is suspended from the four 1.600mm-deep roof trusses spanning 19m.

In order to minimise disruption to access to the sports club beyond the car park, steelwork contractor William Hare had to work quickly on site, using all-bolted connections with no in-situ welding.

By using as simple connections as possible to speed up the erection, the steelwork for the beam was put up over the weekend, thus minimising disruption to the car park beneath.



Left: Perpendicular aluminium fins on the sports beam elevations create a pattern inspired by Newton's



Diagram showing the steel structure, with the sports beam conceived as levity, and the main building as gravity.

THE MAIN SCHOOL STRUCTURE

For steelwork contractor William Hare, one of the challenges was meeting the six-month ordering window for the steel beams, and then dealing with the tight site conditions during the installation – in some places the perimeter fence was just 2m away from the building.

In total, 1,269 tonnes of steel frame is used on the structure, with nearly 2,000 pieces.

On the main school building, asymmetric beams incorporate precast, 200mm-thick concrete floor slabs, which sit on the wider bottom flange of the beam within the 300mm slab depth

Although the structure appears simple on plan, according to Skanska senior project leader Hardip Bansal there were several interesting aspects to accommodate. These included bridges linking the north and south blocks. large projecting box structures on the north and south blocks, and hanger supports to the balcony view ing areas in the north block as well as the third floor of the sports beam.

Steelwork is protected with intumescent coating, where needed, to give four hours of fire protection – this was applied off-site.



The main hall can be used as a performance space with an upper tier of seating.

The sports beam projects over a public ca

rings. Right: The sports beam was erected swiftly, supported by five sets of paired columns.

STEEL FOCUS CO-OPERATIVE GROUP HQ FRIDAY 01/02/2013 12

Spirit of the been ive

Designing a £114m Manchester HQ for the Co-operative Group, 3DReid found inspiration in a traditional symbol of the movement, to produce a building with a real buzz

Text by Pamela Buxton

ith their emph sis on collabo rative industry. co-operative societies have traditionally adopted the beehive as an appropriate symbol for their ethos. It was also a natural inspiration for the architectural form of the Cooperative Group's new £114 million Manchester headquarters, designed by architect 3DReid.

The Co-op decided to invest in a new head office after research indicated that staying put in its current eight offices would require an investment of £180 million over 25 years. Instead, it decided to develop a new building for its own use, but one that would be attractive for sale on the commercial market - for single or multiple occupancy - if desired in the future.

This gave the Co-op the opportunity to consolidate its offices as well as creating a sustainits workers, with a Breeam "outever given to an office building.

Hitchmough. "Sustainability is ment for floor plates no smaller at the very heart of what they are than 2,300sq m but no wider level 11, one to level 15. and what they do."



Each office floor overlooks the central atrium, which is topped with a lattice roof.



able new office environment for SITE PLAN OF THE NOMA DEVELOPMENT

standing" rating - the highest 1 Co-operative Group headquarters 2 Angel Meadows 3 Victoria Station

than 16m, so that no desk would

"The Co-op is an ethical bank looked at many configurations it wrapped the plan around to and fair-trade supporter," says for the 46,000sq m building form a rounded triangle with 3DReid divisional director Mike which would fulfil the require- cores in each corner providing structural stability, two rising to

Open balconies overlook the The site, part of the 8ha be more than 7m away from a triangular atrium. This central so-Noma mixed-use development, window. Mindful of the client's cial space, which is glass-topped is to the north of the city centre brief for connectivity within the at roof level, is in effect the "glue" and bounded by Corporation 16-storey building, the architect that binds the headquarters Street and Miller Street. 3DReid avoided a long thin plan. Instead, and its occupants together, says Hitchmough, as well as acting as an extraction duct for stale air

passing up towards the vents. "The buzz of the building will bleed into the central atrium," he says. "Wherever you sit on the floor plate you can either look out of the window or across through the atrium to see either the Pennines, the Peak District or the city centre.'

The building is tilted due south to optimise natural light, stepping down from the 15th to the 8th level. This last full floor plate includes the staff restaurant and terrace looking across the city.

The design provides 2,800 desk spaces for 3,500 staff, in response to the client's desire to introduce new ways of working, including an element of hot-desking. In so doing, 3DReid has avoided the need for three extra floor levels, thus saving approximately £20 million. The building



DOUBLE-SKIN FACADE

The Co-op building has a double-skin facade to improve Instead, 99% of the glass its thermal performance. The is in flat, triangular panels, thermal line is on the inside of the fully glazed building with the outer skin acting as a a 10mm distortion over a weather-tight thermal buffer to trap solar gain. This void swells from 800mm at the top and bottom to 2.5m in the outward form in contrast to the rational, inner skin.

"We wanted to create something with a real fluidity, mindful that as soon as you have curved glass the cost goes through

the root, says Hitchmough cold bent with a very slight elasticity to them, which gives distance of 4m. This outer skin is attached to the inner using secondary brackets fixed to the primary steelwork. These

A robust, anodised finish to the outer skin was specified at an extra cost to a standard. powder-coated finish to reduce maintenance costs over the life of the building.



A double-facade creates a thermal buffer to improve environmental performance.

ROOF

middle, giving a fluid, dynamic cantilevering arms follow the line of the outer skin.

In association with The British Constructional Steelwork Association and Tata Steel TATA STEEL



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inspiration from the Great Court at the British Museum (which engineer Buro Happold also worked on), five huge steel Vierendeel trusses span the atrium, tied together with a steel framed lattice. Each piece is framed by a pair of 300mmdiameter circular hollow sections, which meet at the ends of the lattice. This lattice was welded on site and installed by the facade contractor. The atrium glass has a 60% solid frit pattern to control light but preserve views out for those



working in the offices. "We wanted to create a roof that provided a window on to the city for the staff," says Hitchmough.

The atrium roof steps down in response to the irregular form of the building.

provides 30,000sq m of office space as well as other facilities such as a 275-seat auditorium in the upper basement. The atrium functions as a temporary exhibition area with a business lounge for visitors, a café, and a meeting space for up to 500 people.

Initially, the design team considered a fully concrete frame but this would have made it difficult to achieve such wide, columnfree spans. Instead, it opted for steel with precast concrete floor slabs for thermal mass. In total the building uses 3,200 tonnes of steel.

"The programme we were working to led us down the steel route," says Hitchmough. "The structure is fully exposed so that the building is clear and honest and legible in how the concrete and steel come together.

"The client was insistent there should be no internal columns so we had to span 16.5m from the atrium to the external wall. This meant the steelwork had to work harder, and there were cost implications. But the client was willing to buy that for the flexibility it gives it down the line."

Hitchmough adds that "longevity and resilience of use was a key aspect of the brief - that's sustainable design as well," making the point that this effectively future-proofs the building so that it will be able to perform to the same standards in a simulated hotter climate of 2050.

The hope is that the new building will operate with at least an 80% reduction in carbon emission and a 50% reduction in energy consumption compared to the current head office complex.

The new offices have exposed concrete soffits, which act as a thermal sponge, and a doubleskin facade which, says Hitchmough, acts as a big thermal duvet. A natural ventilation system draws through 50,000 litres of air per second using 150m of underground concrete earth tube, which passively heats or cools the incoming air.

The Category A office building is the largest commercial office in Manchester, cost £2,200/sq m, rising to £2,500/sq m after fit-out, which is currently underway. According to Buro Happold principal engineer Mark Phillip, it has surprised those who expected a more overtly bespoke solution.

"Anyone financial or legal could move in," he says. "It's a fantastic office building rather than a Co-op building."

According to Hitchmough the new building will be a tool for the transformation of the Coop's business and the wider regeneration of the Noma site.

The building was designed us ing bim, which will also be used for a post-occupancy research project into the building.

For a video case study of this building, go to www.steelconstruction. info/Video_case_studies

PROJECT TEAM

Architect 3DReid **Client** Co-operative Group Structural engineer Buro Happold Contractor **BAM** Construction Steelwork contractor Fisher Engineering



MAIN OFFICE STRUCTURE

Use of steel enabled the required large, column-free floors. The steel frame is spliced at every third level and is tied to the concrete cores on every level via connecting plates welded by steelwork contractor Fisher Engineering on to plates cast in to the cores.

Fisher used 2,000 tonnes of cellular beams, chosen because of their service holes and also their ability to achieve a shallow floor depth. These fabricated steel I- sections are 590mm deep and spaced 3m apart. They span a maximum of 16.5m. These were combined with precast concrete coffer units for thermal mass. These are notched to sit on the bottom flanges of the beams. There is a 110mm concrete topping and a 400mm-deep lightweight raised floor for any additional services.

In total, there are 18 types of fabricated beams with varying flange and web thicknesses but a constant depth - the exception being the corners, where the rounded Fabsec steel beams are deeper at 900mm for extra stiffness.

"The main challenge." says Fisher senior project manager Barry Craig, "was that because the steelwork members have the bottom flange exposed in their final state, we had to erect them to very tight tolerances and had to have a high decorative paint finish.

Logistically, the steel frame erection needed careful coordination between the trades. with Fisher erecting three levels on one side at a time and then moving on to the next side while the precast coffer units were installed and the concrete topping cast. This was finished in time for Fisher to start on the next three levels using a lightweight cherry picker on the completed slab.



The steel structure enabled the design team to meet the tight programme and achieve the desired spans.

How to win the top green ratings

Breeam ratings are more important than ever. We look at the most cost-effective ways of achieving the highest three standards in five common sectors

and marketing tool.

According to statistics released amount in 2008. Project registra- into planning policy. tions have also increased from 20,000 to 44,000 since 2008 from 2010.

ENERGY

Submetering of

of areas and/or

duction of CO2

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ENERGY

COLOG

POLLUTION

POLIUTTON

ninimising watercourse

pollution, reduction of

light pollution, noise

attenuation

Low flood risk zone,

departments

substantial energy

uses, efficient externa

lighting, sub-metering

MAKE EVERY

PENNY COUNT These diagrams summarise the

most cost effec-

tive routes for

achieving each

Breeam rating.

For a "very good"

rating, designers

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fied under Breeam keting at the Building Research has doubled in the Establishment (BRE), which adlast two years, as the ministers the scheme. "It is also value of a property portfolio."

Breeam standards are also befloor space - nearly four times the local authorities writing Breeam Zero tackles this by setting out

you've done the worst possible Wilson, director of Building En- study buildings from five differ-"Breeam is increasingly used gineering at Aecom and project ent sectors (see diagrams below). by owners and developers to help director of the recent Target Zero While the base case buildings are

WATER

Water meter

sanitary fittings

HAR

WASTE

floor finishes

Construction site waste

management, storage

of recyclable waste, use

of recycled aggregates,

low flow

major leak

detection

planning to attain certain levels to start, according to Wilson. of Breeam."

But while Breeam's relevance sustainability rating attracting a lot of interest from the and profile have undoubtedly system becomes an investment community as a means increased, finding the most ecoincreasingly powerful planning of protecting and enhancing the nomic way of achieving these standards can be a complex and opaque issue. Research carried last month, Breeam has now cer- ing increasingly linked to plan- out by Aecom and costed by tified a total of 44 million sq m of ning, with a growing number of Sweett Group as part of Target the most cost-effective ways of "If you just meet Building Regs achieving the Breeam ratings of "very good", "excellent" and "outwith a sharper upward trend you can get away with," says Ant standing" for five standard case

ANAGEMENT

1ANAGEMENT

Commissioning, considerate

constructors, construction site

mpacts, security, building use

OFFICE

192 9 2 2 2 4

Ant

[RANSPOR]

Public transport links.

proximity to amenities,

ravel plan, maximum

car parking, cyclist

showers, lockers and

facilities - racks,

changing

VATER

nitary supp

include the direct impacts from the frame, so the results are relevant irrespective of framing material chosen. It also identifies the costs of

achieving these ratings compared with a base case version of the buildings that, in terms of operational carbon, met the minimum requirements under Building Regulations Part L (2006).

In all five building types - distribution warehouse, supermarket, office, secondary school, mixed-use development - relatively small uplifts of between 0.04 and 0.2% were needed to achieve "very good", with slightly more - between 0.4 and 1.8% to achieve "excellent". As might be expected, the big difference comes when achieving the top rating of "outstanding". The distribution warehouse was the cheapest, requiring a cost uplift of 4.8%, followed by mixed use (5%) and secondary school (5.8%). The office and supermarket were the most costly to attain "outstanding", requiring a 9.8% and 10.1% uplift respectively.

Involving a Breeam assessor early is another way of achieving otal floor area certi- Guy, head of sustainability mar- "It's often now a requirement of Breeam credits and is a good way

HEALTH AND

WELLBEING

lighting, internal and

external lighting levels,

contamination, reducing

preventing microbial

the use of VOCs,

thermal comfort,

lighting zones and

controls, acoustic

HEALTH AND

WELLBEING

FAI TH AN

ndoor air quality

MATERIALS

Material specification

responsible sourcing

of materials and

landscaping

nsulation. robust

details, A-rated hard

performance

High-frequency

"If you have a good Breeam asidea of the cost of what's required, and can tell you the cheapest way of achieving the right credits to get certain ratings," he says.

"One of the things that came out of Target Zero is the cost differences that get the same outcome in Breeam." To score well on Breeam, it's vital to get the energy performance right. "Do all you can with the fabric

'Get the building to consume far less energy in the first place

of the building," he says. "First get the building to consume far less energy in the first place to get the loads down, and then control its systems efficiency.

right. It's not just about insulation and low U-values - sometimes you have to let the heat out to limit solar and internal gains.

Capital cost uplift (%) to achieve Breeam Capital construction cost (£m) VERY GOOD EXCELLENT OUTSTANDING 4.8 DISTRIBUTION 19.4 0.04 0.4 WAREHOUSE SUPERMARKET 16.4 0.2 1.8 10.1 SECONDARY 22.5 0.2 0.7 5.8 SCHOOL OFFICE 61.7 0.2 0.8 9.8 MIXED USE 36.7 0.1 1.6 5.0

drive sustainability, says Simon research into sustainable design. steel-framed, Breeam does not Target Zero research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing the average cost increase required to secure the top Breeam research showing to secure the top Breeam research showing to secure top Breeam research

ENERGY

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Refrigerant leak

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POLLUTION

Low flood risk zone,

minimising watercourse

pollution, reduction of

light pollution, noise

attenuation

ENERGY

MIXED USE

Commissioning, considerate constructors,

onstruction site impacts, security,

MANAGEMENT

MANAGEMENT

WATER

/ATFR

WATER

Water meter, low

flow sanitary fittings

ajor leak detec

Breeam "outstanding" is a sessor on your job they'll have an tough challenge, representing the top 1% in terms of building performance, says experienced Breeam assessor Clare Lowe, who is associate director of environmental consultancy Southfacing.

"With all types of buildings, 'outstanding' is a big ask, particularly for speculative buildings," she says. "You need to have a lot in your favour in terms of location credits, including public transport and a brownfield site in the first place, to give you a good

A frequent stumbling block is achieving the compulsory 10 out of 15 energy performance credits needed to attain "outstanding". Gaining sufficient water credits can also be a challenge, she adds, since they sometimes push clients towards unfamiliar products or technologies that they may not be comfortable with. This can be a particular issue with hotels. For retail, the key issues are lighting "Try to get the energy balance and in the case of supermarkets, refrigeration.

Since they tend to require lighter floor structures, says Lowe, steel-framed buildings Comfort issues - health and well- generally benefit under Breeam being - are also vitally important." from using less material, while

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reeam ratings.	
WELLBEING	
High-frequency lighting, internal and external lighting levels, preventing	

issues.

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car parking capacity



HEAL

microbial contamination

Reducing the use of VOCs,

thermal comfort lighting

Construction TRANSPORT site waste Public transport links, management proximity to amenities, storage of travel plan, maximum recyclable waste use of recycled aggregates

composting

RANSPORT ravel information oint, pedestrian and clist safety

ighting, su of areas and/or departments

ENERGY





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Wilkinson Eyre's Crystal building for Siemens in London's Royal Victoria Dock is rated Breeam "outstanding" and LEED Platinum.

the often prefabricated nature of steel structures can also count towards a better rating, tending to generate less waste on site. But steel's potential for recyclability is not yet rewarded, although this might change if future versions of Breeam give more weight to end-of-life

"Steel is more sustainable in a whole-life argument because of its re-use capability," says Wilson. "Recycling a building asset down and starting again."

Breeam's growing relevance year's Good Practice Guidance: dustry bodies. This referred to erence for required sustainable standards.

might be better than ripping it rating scheme is likely to grow Manchester. BRE is currently as it expands from new con-seeking further pilot projects to struction and in-use assessment to planning was noted in the last schemes into refurbishment. opportunities and barriers for Breeam for domestic refurbish-Sustainable Design & Construc- ment was launched last year and scheme is expected to launch this tion, produced by the TCPA, a standalone version of Breeam autumn with the next general up-BRE and a number of other in- for non-domestic refurbishment date to Breeam due in 2014. is being developed. Pilot proseveral examples of planning au- jects include university buildthorities using Breeam as a ref- ings, two London office schemes of achieving Breeam ratings for difand a department store, and Hanover House on the Co-opera- at www.steelconstruction.info/ The importance of the Breeam tive Group's Noma site in central **Target_Zero#Breeam_results**

test out the criteria and identify sustainable refurbishment. The

Research into the comparative costs ferent building types can be found

Foster's Breeam "excellent"-rated Walbrook House in the City of London is one of the increasing number of buildings being assessed under Breeam

