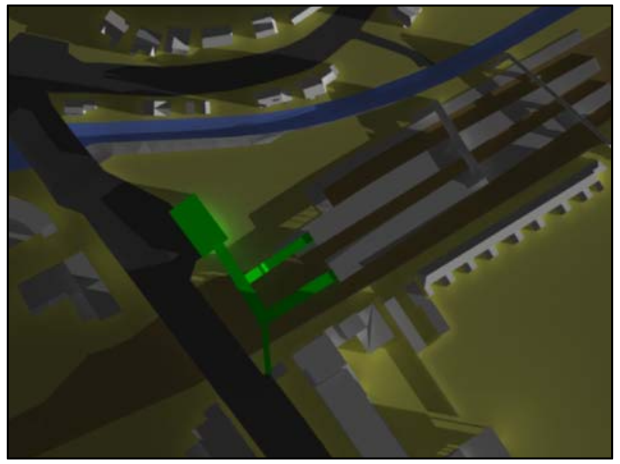
APPENDIX I: DAYLIGHT, SUNLIGHT, OVERSHADOWING AND SOLAR GLARE

Appendix I-1: Permanent and Transient Shadow Analysis



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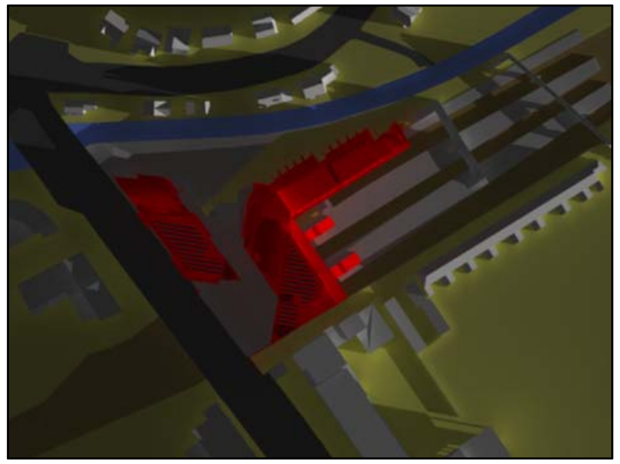

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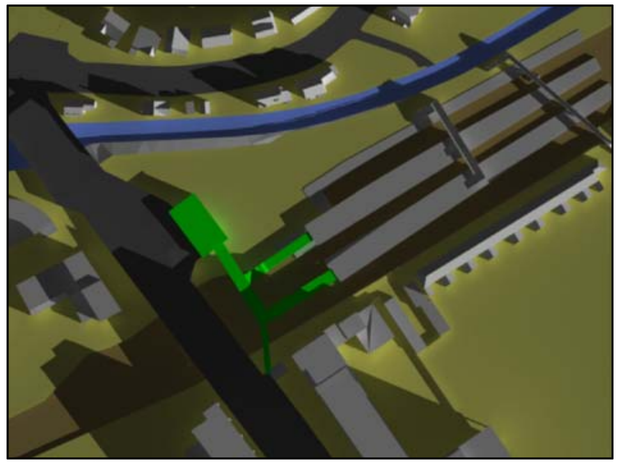

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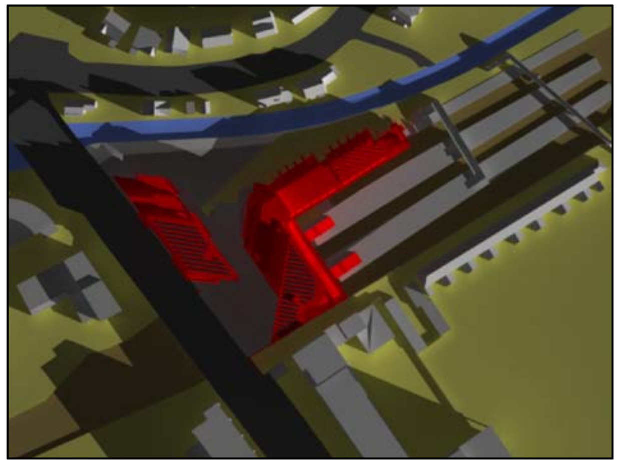

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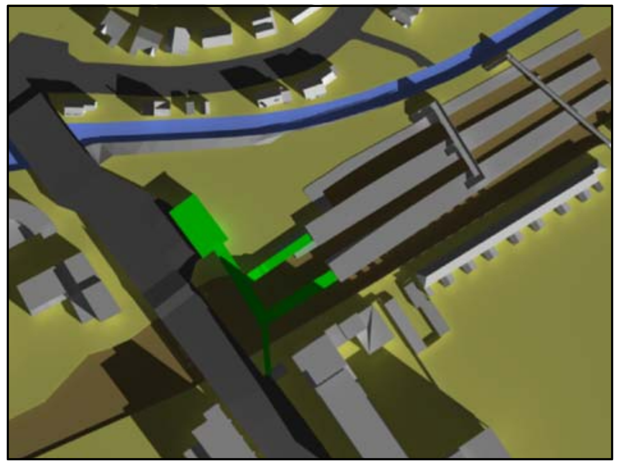

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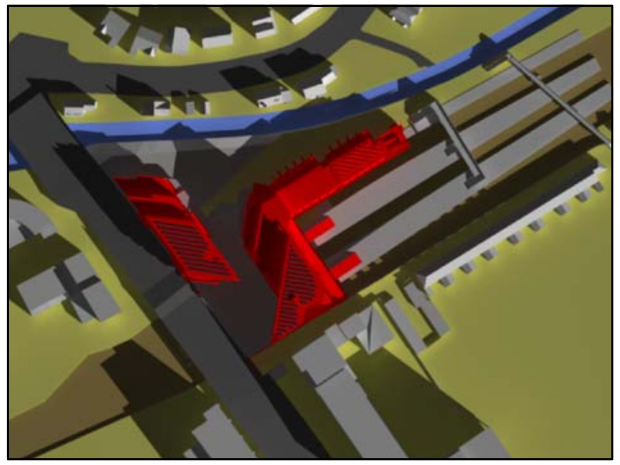

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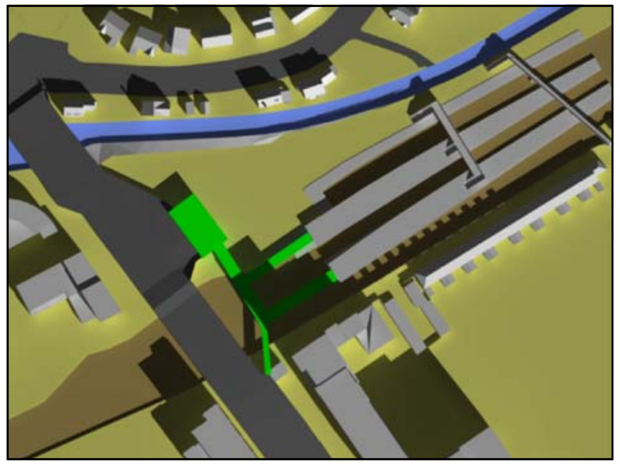

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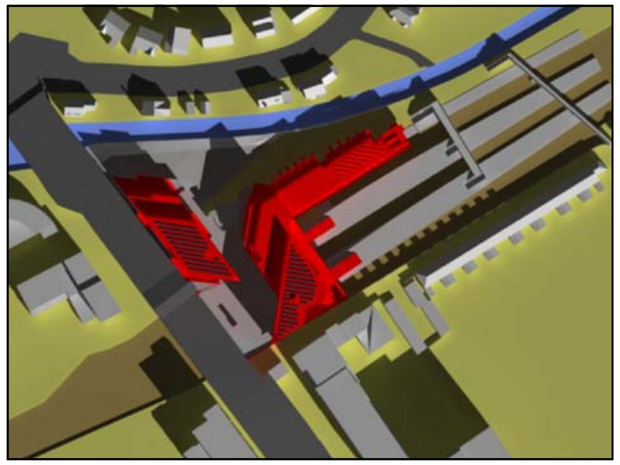

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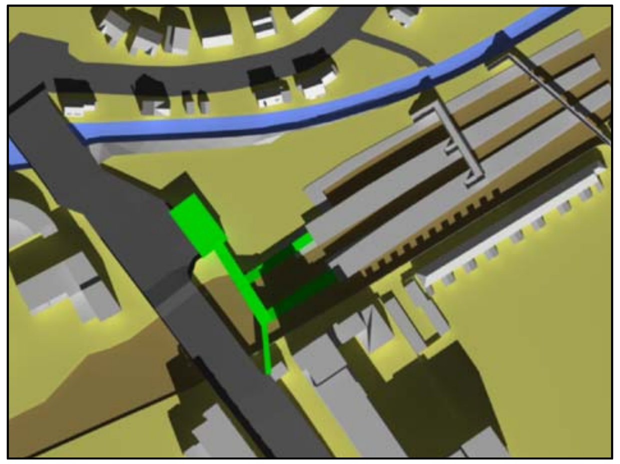

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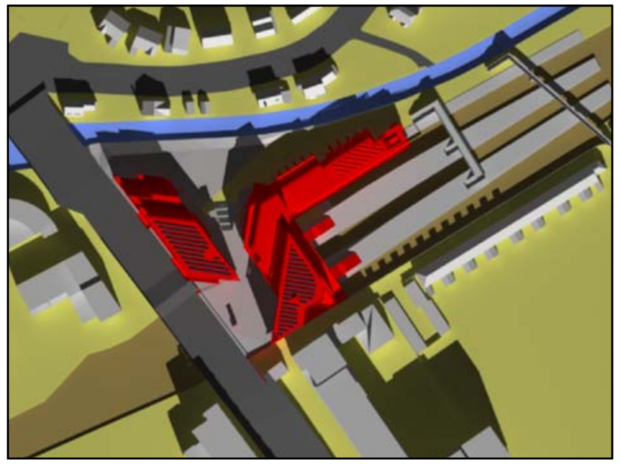

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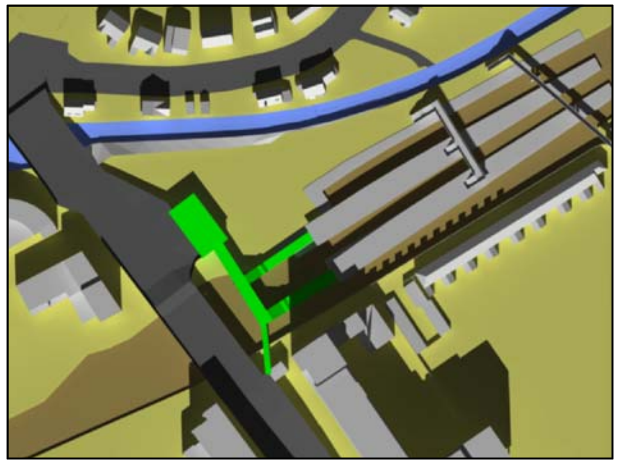

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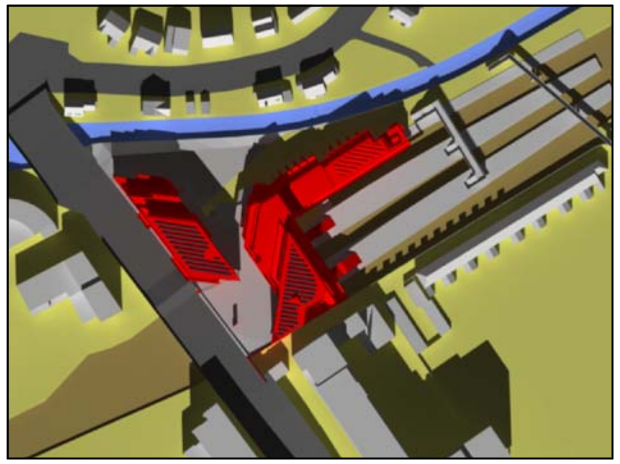

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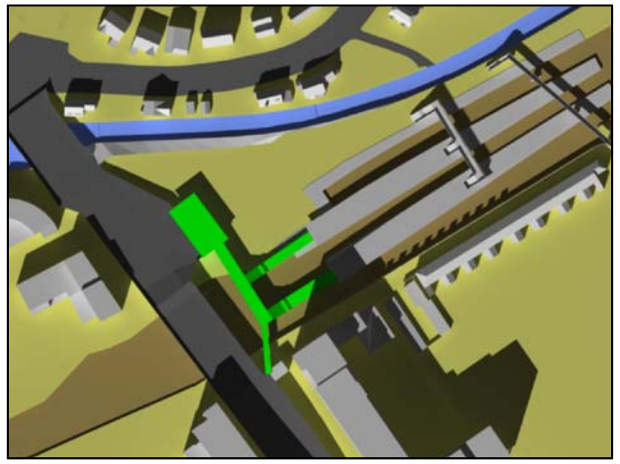

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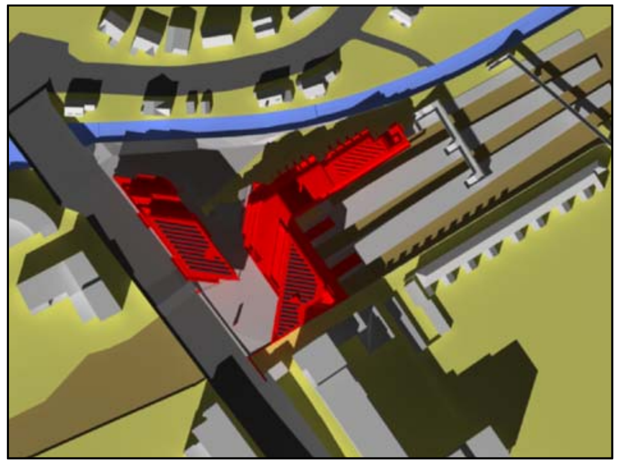

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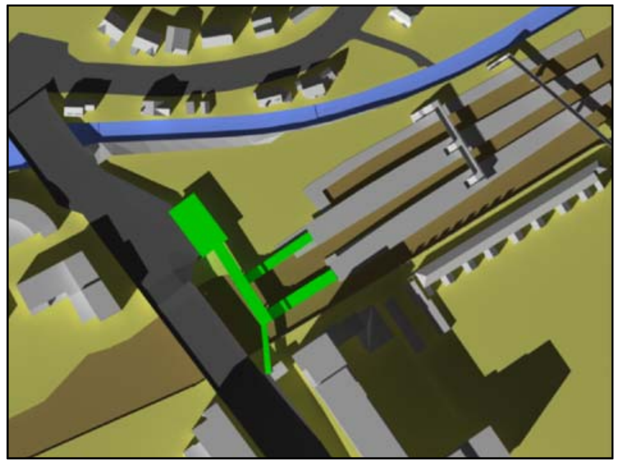

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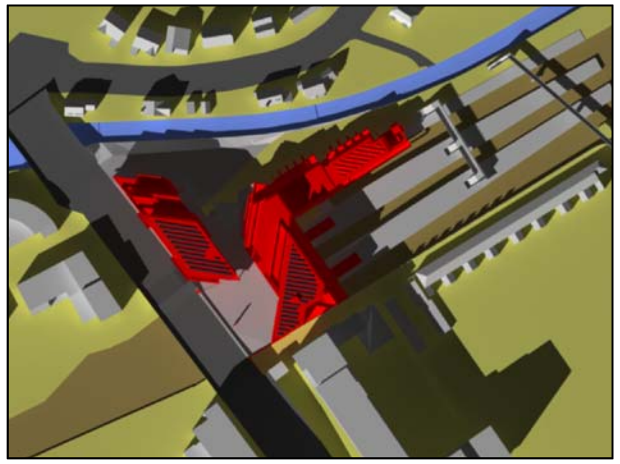

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BEHAN PARTNERSHIP LLP
3D CAD MODEL

SURVEY DRAWINGS
EWL/14418-SHEET_1, 2, 3 (REV 1), 4 - 14

ROLFE JUDD ARCHITECTS
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SCHEME 7 STOREY PROPOSED SKETCHUP MODEL

PLANNING ARCHIVE MATERIAL
RICHMOND UPON THAMES PLANNING DEPT
10 MARYS TERRACE
PROJECT DESIGN CONSULTANTS
AB/01 01 REV A

2A COLE PARK ROAD
RICHARD EWEN ARCHITECTS
REA/235/01, 02, 03.

EXISTING BUILDINGS SHOWN IN GREEN
PROPOSED DEVELOPMENT SHOWN IN RED
RIVER CRANE SHOWN IN BLUE
PROPOSED AMENITY AREA SHOWN IN DARK GREEN

No.	Revision/Issue	Date

behan partnership LLP
chartered surveyors

Behan Partnership LLP
Chartered Surveyors
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Project Name and Address

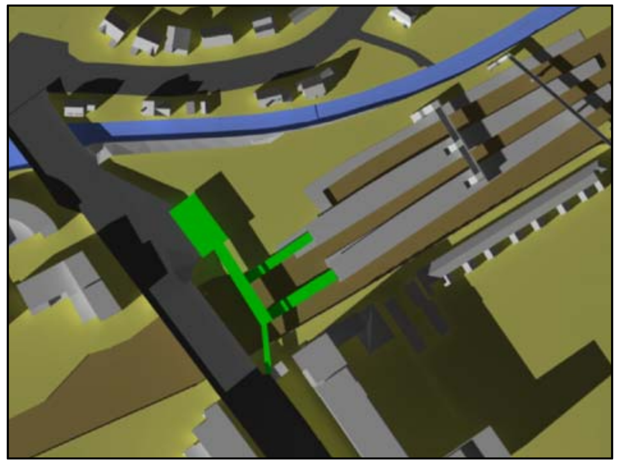
TWICKENHAM STATION
TWICKENHAM
LONDON

Drawing Description

SHADOW ASSESSEMENT
TWICKENHAM STATION

MARCH 21ST
SPRING EQUINOX

Project Reference: 2010554
Date: 16/3/2011
Scale: NS
Drawing Sheet No: 554/SA/201



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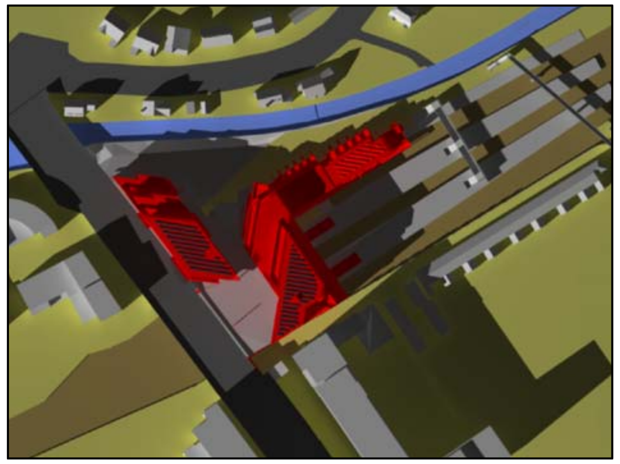

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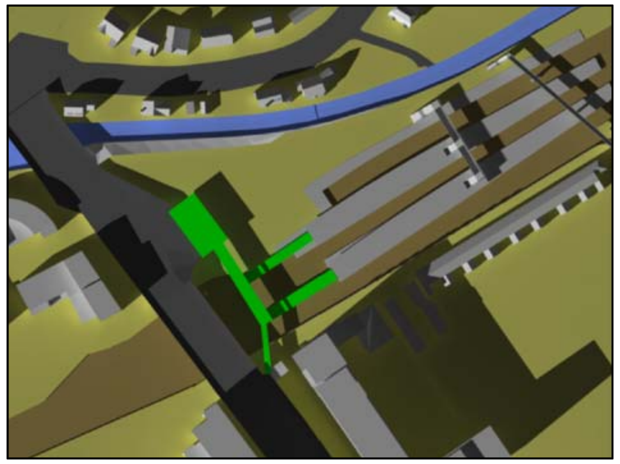

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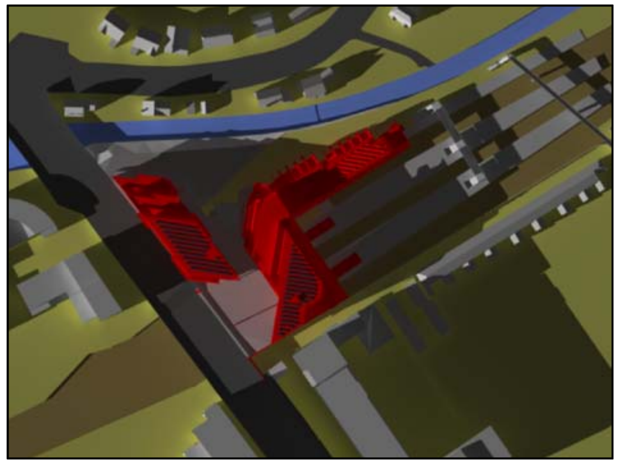

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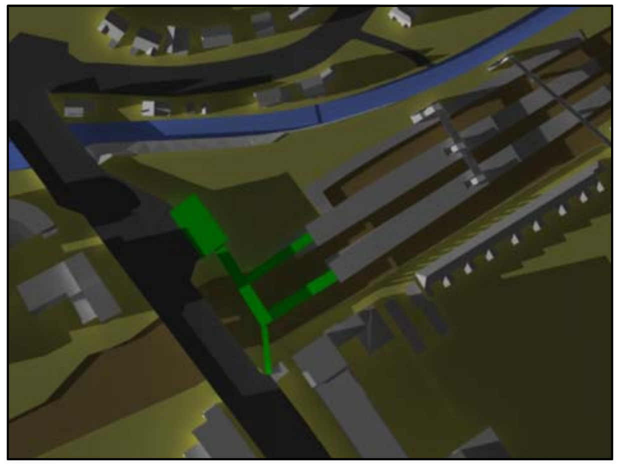

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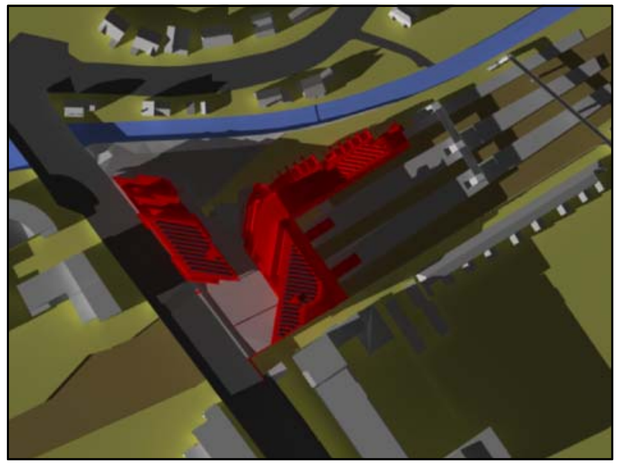

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PROPOSED DEVELOPMENT
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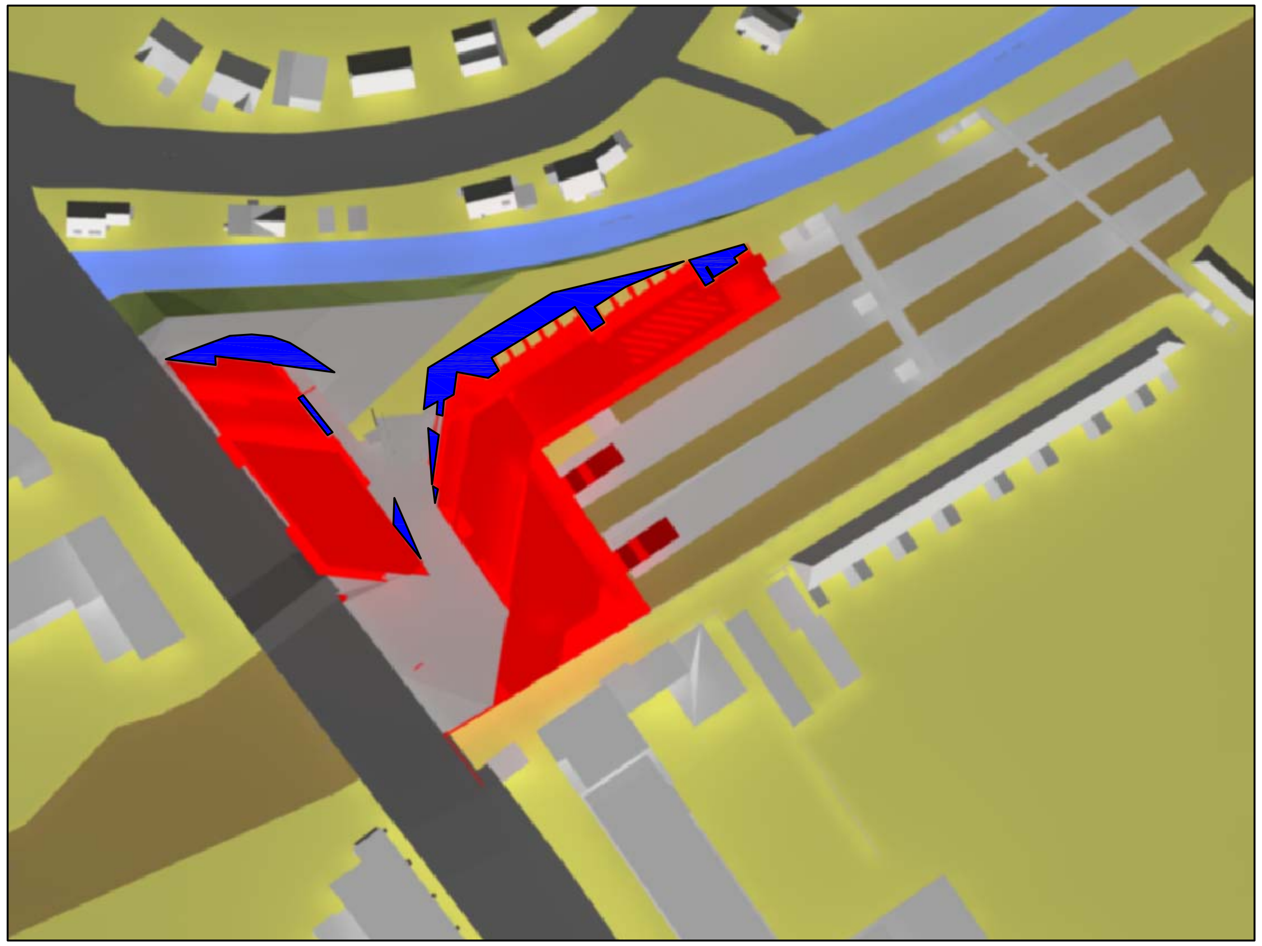

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10 MARYS TERRACE
PROJECT DESIGN CONSULTANTS
AB/01 01 REV A

2A COLE PARK ROAD
RICHARD EWEN ARCHITECTS
REA/235/01, 02, 03.

PERMANENT SHADOW IN DARK BLUE
EXISTING BUILDINGS SHOWN IN GREEN
PROPOSED DEVELOPMENT SHOWN IN RED
RIVER CRANE SHOWN IN BLUE
PROPOSED AMENITY AREA SHOWN IN DARK GREEN

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TWICKENHAM STATION
TWICKENHAM
LONDON

Drawing Description
SHADOW ASSESSEMENT
TWICKENHAM STATION

MARCH 21ST
SPRING EQUINOX

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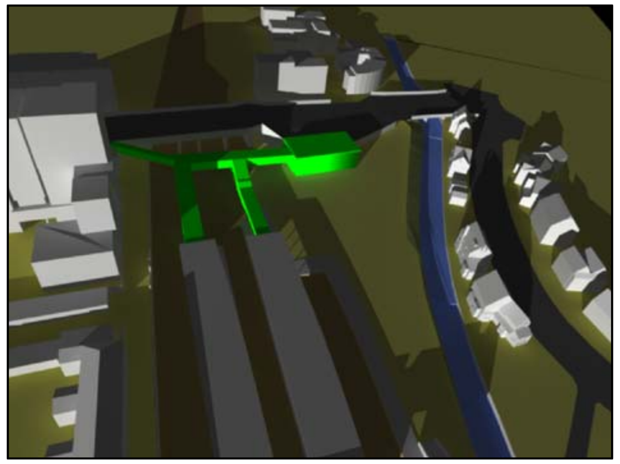
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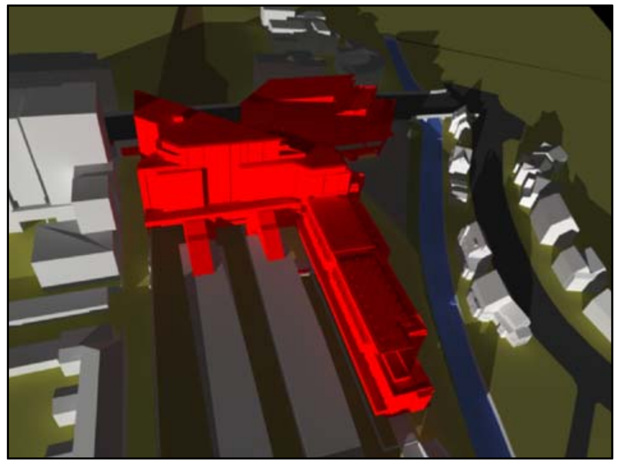
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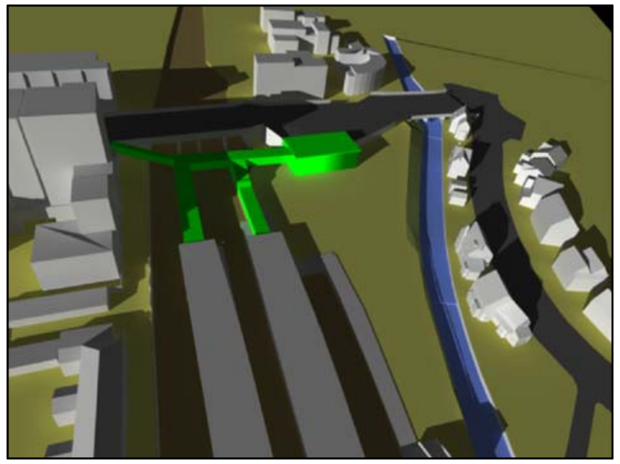
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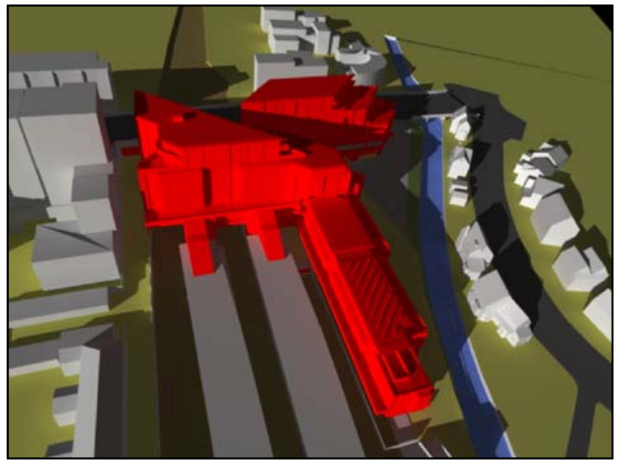
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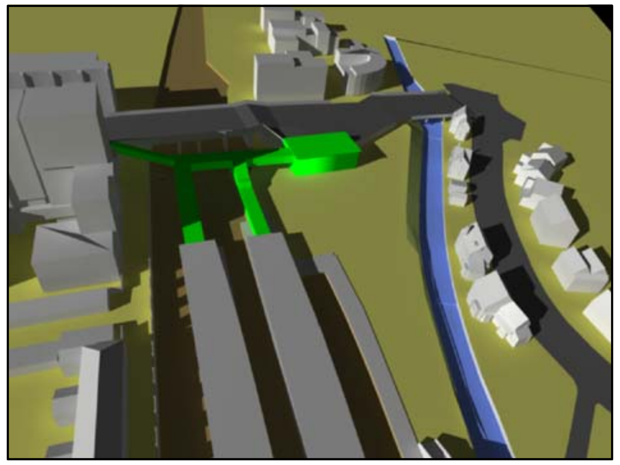
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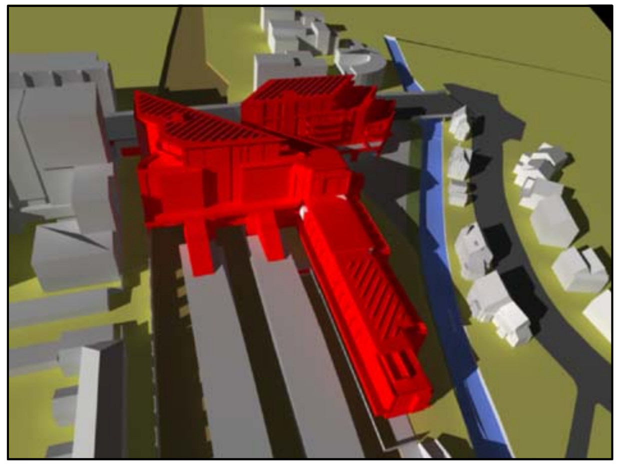
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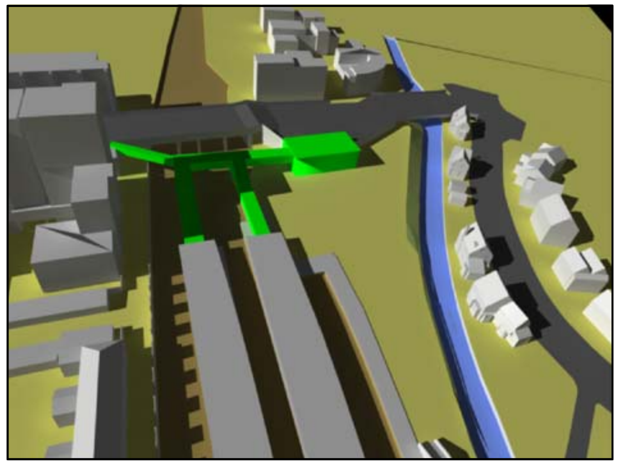
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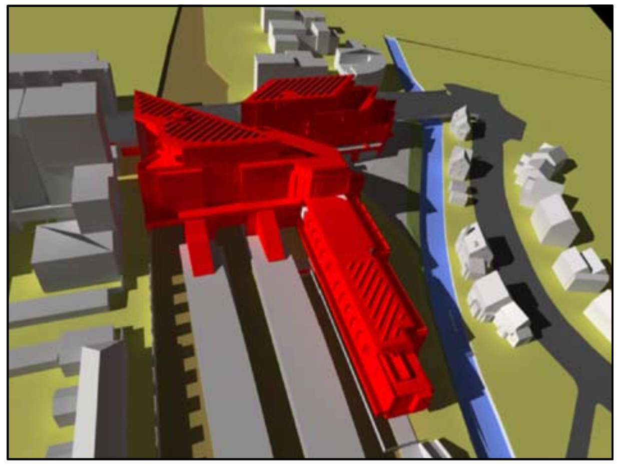
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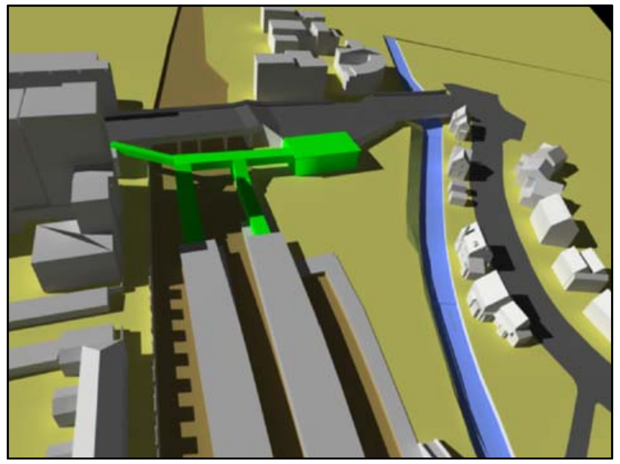
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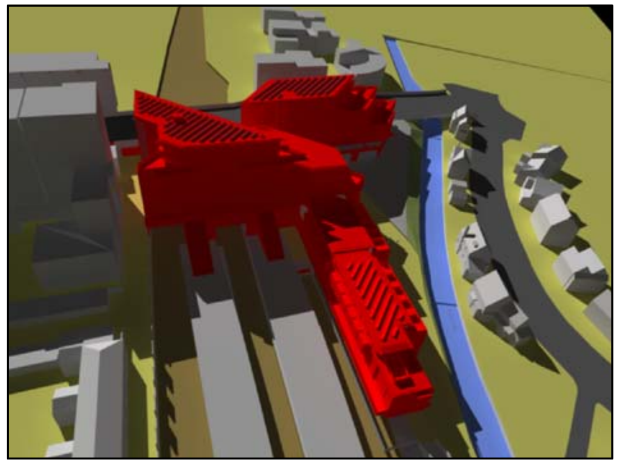
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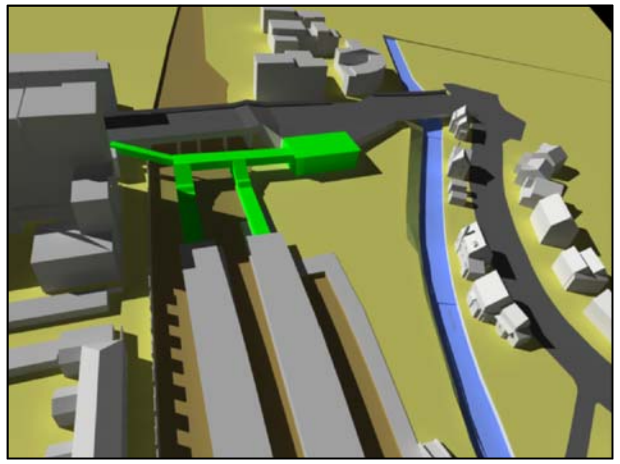
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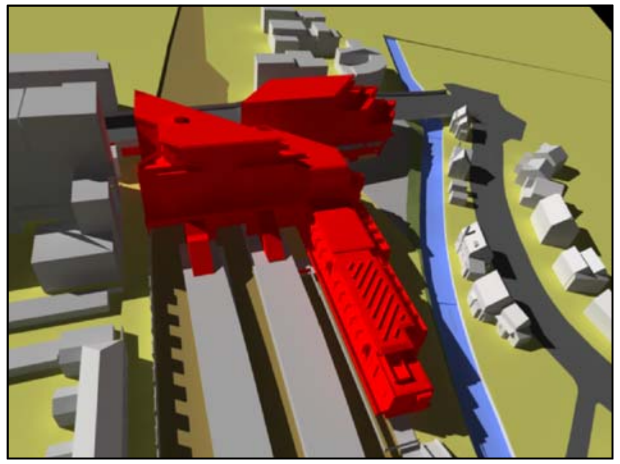
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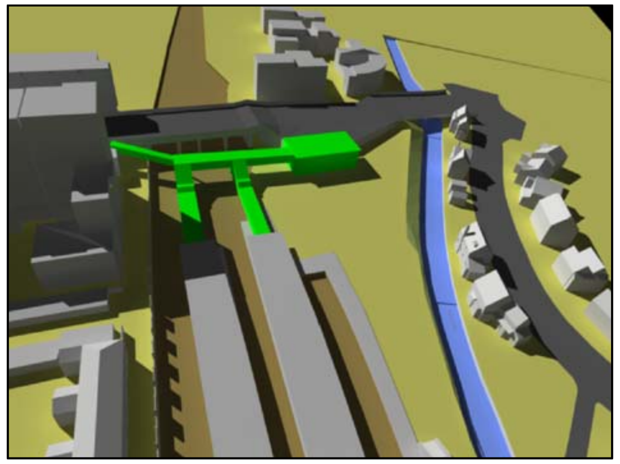
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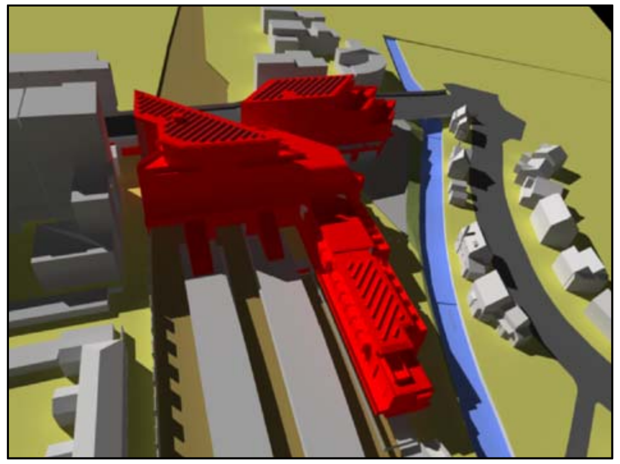
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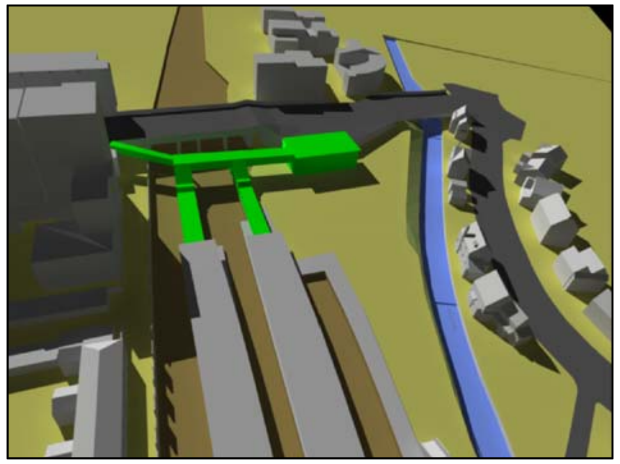
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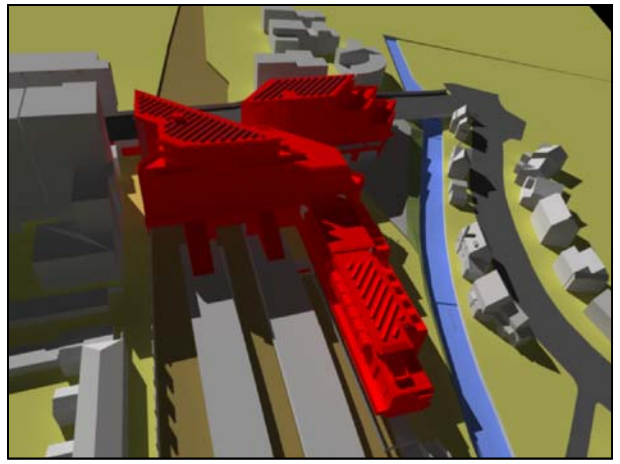
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2A COLE PARK ROAD
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Drawing Description

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Project Reference: 2010554	Drawing Sheet No: 554/SA/203
Date: 16/3/2011	
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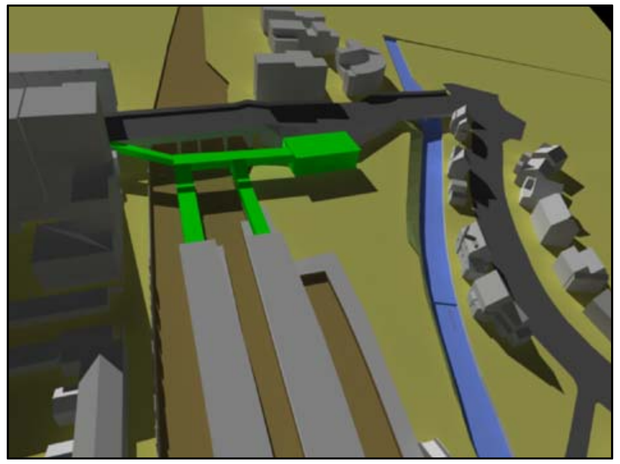
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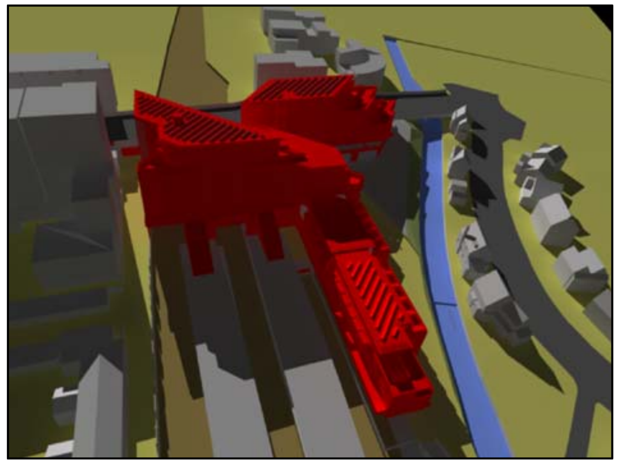
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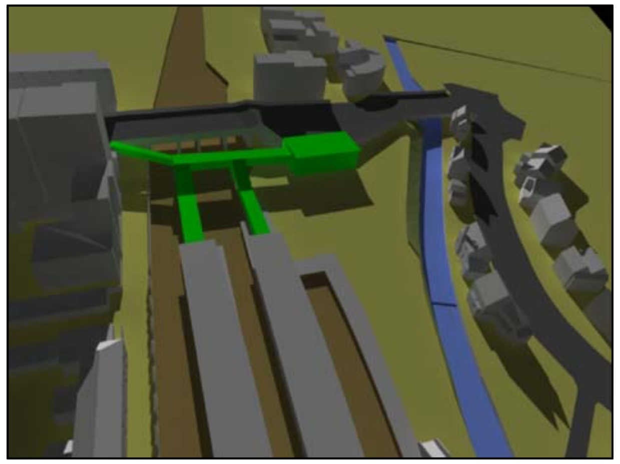
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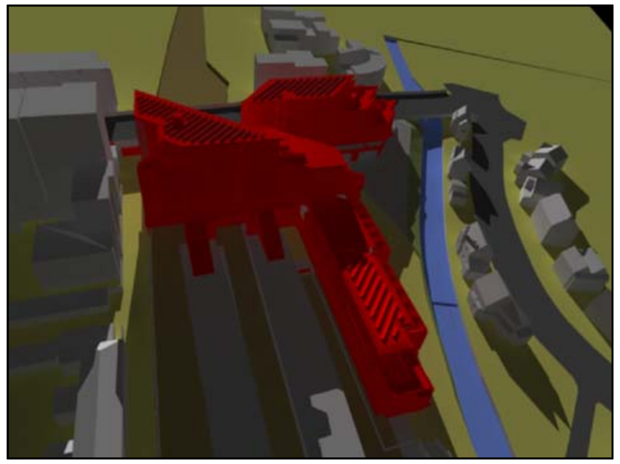
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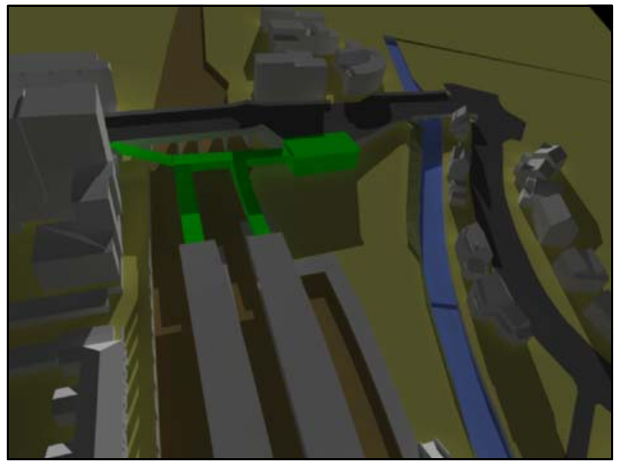
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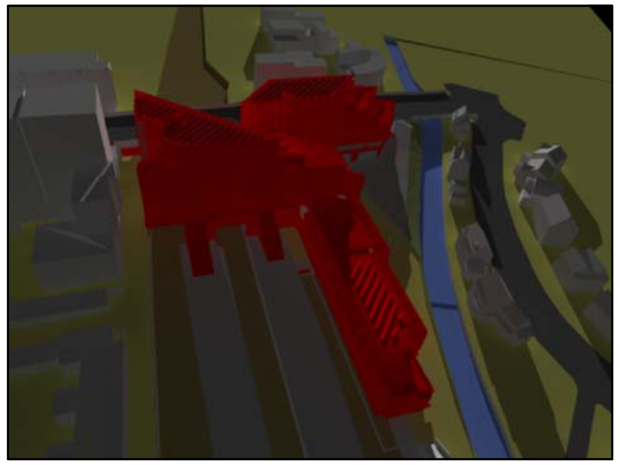
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BEHAN PARTNERSHIP LLP
3D CAD MODEL

SURVEY DRAWINGS
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ROLFE JUDD ARCHITECTS
4674/T(20)E01 - E06, P00, P01 - P07, P-1, P-1M, S01 - S04.
SCHEME 7 STOREY PROPOSED SKETCHUP MODEL

PLANNING ARCHIVE MATERIAL
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10 MARYS TERRACE
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2A COLE PARK ROAD
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REA/235/01, 02, 03.

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TWICKENHAM STATION
TWICKENHAM
LONDON

Drawing Description
SHADOW ASSESSEMENT
TWICKENHAM STATION

MARCH 21ST
SPRING EQUINOX

Project Reference: 2010554
Drawing Sheet No: 554/SA/204
Date: 16/03/2011
Scale: NS

Appendix I-2: BRE Information Paper (Solar Dazzle)

Building Research Establishment
Information Paper
CI/SfB 1976 (N6)
IP 3/87
April 1987
bre Latest research information and how to apply it

Solar dazzle reflected from sloping glazed facades

P J Littlefair MA PhD

Glare or dazzle can occur when sunlight is reflected from a glazed facade. For vertical facades this problem usually occurs only when the sun is low in the sky; but some types of modern design incorporate sloping glazed facades which can, under certain circumstances, reflect unwanted high altitude sunlight into the eyes of motorists, pedestrians and people in nearby buildings. Addressed to architects, consulting engineers, planning consultants and planners, this paper presents a new method which can be used at the design stage to calculate whether such solar dazzle will be reflected from a proposed building facade.

INTRODUCTION

With the increasing interest in passive solar design many architects have come to realise that the design of the building facade is critical if ambient energy (daylight or solar radiation) is to be used to the full. Architects have therefore begun to investigate innovative forms of facade design. One radical idea has been to experiment with departures from the traditional vertical facade. A facade which slopes back from the vertical is able to capture more daylight and solar heat gain. Conversely a facade which slopes forward, so that the top of the building forms an effective overhang, is more shaded from the sun's rays than a vertical facade, which may be important if overheating is likely to be a problem.

Another important development has been the production of new forms of coated glazing which can be chosen[1] to reflect heat, absorb heat, reflect daylight glare or reduce radiative heat loss. These types of glazing have found widespread application.

Coated glazing tends to reflect sunlight; and while this property may be desirable to the occupants of the glazed building, it can be a nuisance to the owners of adjoining property, or to road users outside[2]. Even ordinary glass can be reflective enough to cause problems in this respect. Generally speaking vertical mirror glazed facades only create difficulties when the sun is low in the sky (Figure 1), near dawn or sunset. However, where the reflective glazing leans back from the vertical high altitude sunlight can be reflected nearly parallel to the ground (Figure 2). This can cause glare or dazzle for motorists, or for people in adjoining buildings. In the UK at least one building with a reflective, sloping facade has brought complaints of solar dazzle from the occupants of adjacent property[3-5].

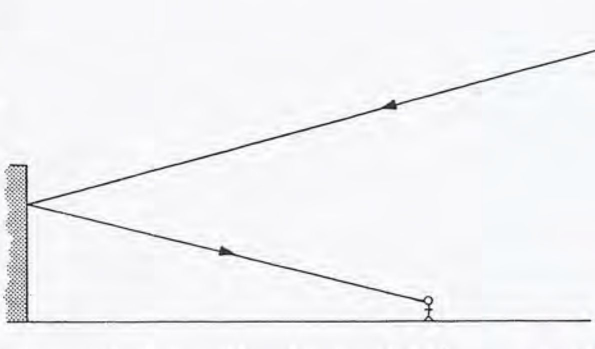


Figure 1 Reflection of low altitude sunlight from a vertical facade

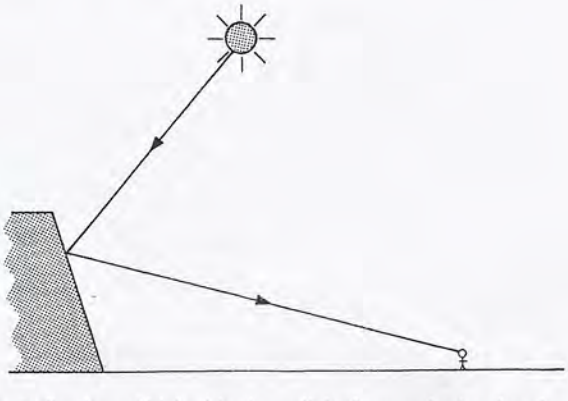


Figure 2 Reflection of high altitude sunlight from a sloping facade

Building Research Station
Garston
Watford WD2 7JR
Telephone: 0923 674040
Telex: 923220

Fire Research Station
Borehamwood
Hertfordshire WD6 2BL
Telephone: 01-953 6177
Telex: 8951648

Princes Risborough Laboratory
Princes Risborough
Aylesbury
Buckinghamshire HP17 9PX
Telephone: 084-44 3101
Telex: 83559

Scottish Laboratory
Kelvin Road
East Kilbride
Glasgow G75 0RZ
Telephone: 03552 33001

▲Technical enquiries to ▲

In some cases the sloping facade may be a convenient and attractive component of a passive solar building. However it is very important that the possible effects of unwanted external solar reflection are considered at the design stage. Unfortunately until now the only practical way of doing this has been to embark on model studies which can be expensive and difficult to carry out.

This paper presents a new technique which can be used to predict solar reflection at the design stage. From simple input data the times (if any) of year at which reflected dazzle could occur, and the total number of hours for which sunlight would in practice be reflected, can both be calculated. At the heart of the technique is the mathematical modelling of reflection from a sloping plane. It is necessary to obtain the relationship between the angles of incidence and reflection, to derive the sun positions at which solar dazzle may be a problem in each particular case.

GEOMETRY OF REFLECTION

Where sunlight is reflected from a vertical facade it is easy to work out the geometry of reflection. Suppose the solar altitude is h_2 and its azimuth (relative to the perpendicular to the facade) ϕ_2. Then the reflected ray will have an altitude

$$h_1 = -h_2 \qquad (1)$$

and an azimuth (relative to the facade normal) of

$$\phi_1 = -\phi_2 \qquad (2)$$

For the sloping facade the derivation of the direction of the reflected ray is much less trivial. Let the slope of the facade back from the vertical be σ. Then it can be shown that the reflected ray will have an altitude h_1 and azimuth ϕ_1 if the sun's altitude h_2 is

$$\sin h_2 = \sin 2\sigma \cos h_1 \cos\phi_1 - \cos 2\sigma \sin h_1 \qquad (3)$$

and its azimuth ϕ_2 (again relative to the facade normal) is given by

$$\tan\phi_2 = \frac{-\sin\phi_1}{\cos 2\sigma \cos\phi_1 + \sin 2\sigma \tan h_1} \qquad (4)$$

Equations 3 and 4 can be derived by using matrix equations to transfer into, and out of, a coordinate system perpendicular and parallel to the sloping facade. A full description of the derivation is given in Reference 6.

APPLICATION OF THE EQUATIONS

Equations 3 and 4 can be used as the basis of a prediction method for reflected sunlight from sloping facades. Around the proposed building key areas will have been identified where solar dazzle would be unwelcome. These would include road junctions, pedestrian crossings, other road hazards, windows of nearby buildings and sports areas such as tennis courts. For these points the altitude and azimuth angles h_1 and ϕ_1 of the four corners of the sloping facade can be readily measured or calculated from site plans.

Application of equations 3 and 4 then gives a set of (h_2, ϕ_2) points which bound the sun positions at which reflection can occur. These points can be plotted on a sunpath diagram to give times of day and year at which reflected sunlight is likely to be a problem.

WORKED EXAMPLE

Figure 3 illustrates, in plan and section, the geometry of a simple example. Point P represents a critical point where access vehicles encounter a pedestrian crossing as they approach a building with a sloping facade LMNO. To assess the risk of reflected solar dazzle at this point we first evaluate the angles of reflection for points on the perimeter of the sloping facade.

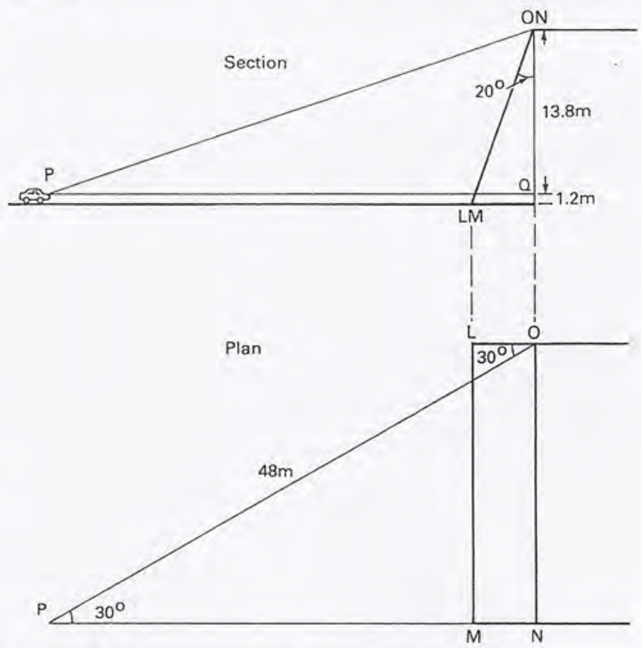


Figure 3 Section and plan of an example situation

Consider for example, reflection from point O at the top corner of the facade. Taking O as the temporary origin of our coordinate system, we note that the altitude h_1 of P is given by

$$\tan h_1 = \frac{\text{Height of P above O}}{\text{Distance of plan}}$$

$$= -\frac{13.8}{48} = -0.2875$$

therefore $h_1 = -16°$

Here h_1 is negative because P is actually below O (Figure 3). The azimuth ϕ_1 of P relative to the facade normal at O can be read off the plan:

$$\phi_1 = 30°$$

Applying equations 3 and 4 we obtain

$$\sin h_2 = \sin 2\sigma \cos h_1 \cos\phi_1 - \cos 2\sigma \sin h_1 \quad (3)$$

With slope $\sigma = 20°$ this gives

$$\sin h_2 = \sin 40° \cos 16° \cos 30° + \cos 40° \sin 16°$$

$$= 0.7462$$

therefore $h_2 = 48\frac{1}{4}°$

$$\tan\phi_2 = \frac{-\sin\phi_1}{\cos 2\sigma \cos\phi_1 + \sin 2\sigma \tan h_1} \quad (4)$$

$$= \frac{-\sin 30°}{\cos 40° \cos 30° - \sin 40° \tan 16°}$$

$$\phi_2 = 46\frac{1}{4}°$$

Thus sunlight will be reflected from this corner of the facade if the sun's altitude is 48¼ and its azimuth (relative to the facade normal) is 46¼°. If the facade were facing due south, this critical azimuth would be 46¼° west of south.

This calculation can be repeated for other points on the edges and corners of the facade, and a locus of points can be constructed which encloses the sun positions at which reflection could occur. For our example building this is illustrated in Figure 4.

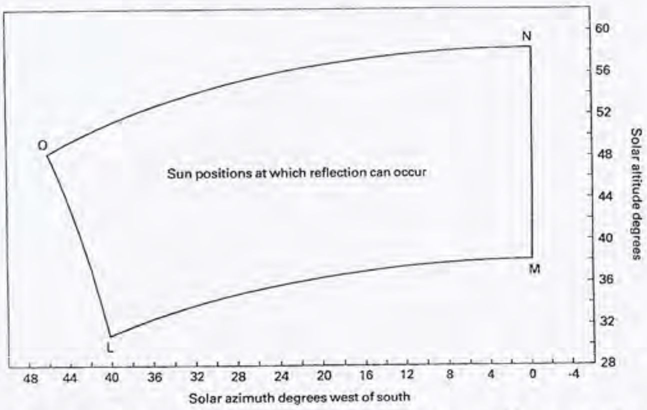


Figure 4 Sun positions at which solar reflection could occur in the example shown in Figure 3

The next step is to plot this locus on a sunpath diagram, to assess the likelihood of reflection occurring during particular hours of the day. Figure 5 illustrates the BRE Sunlight Availability Protractor[7] which for the UK is ideally suited for this application as it also gives the probability of bright sunshine occuring at any time of the year. These are the small decimal numbers above and below the sunpaths (the longer set of heavy curved lines). The sunpaths given here are for the latitude of London (51°). However the method can be used for any location if the correct sunpath diagram is available.

The angular zone of potential reflection illustrated in Figure 4 can be plotted onto the sunlight protractor using tracing paper and the angle scales on the protractor. The tinted zone on Figure 5 shows the result for our example. Inspection reveals that reflected solar dazzle can occur between 1200 and 1400 hours GMT (1300-1500 BST from April onwards), from mid-March to mid-May, and from mid-July to mid-September; around 240 hours per year. The protractor indicates that during these periods sunlight is obtained for just under half the time. Therefore solar dazzle would occur at point P (Figure 3) for just under 120 hours per year.

DISCUSSION

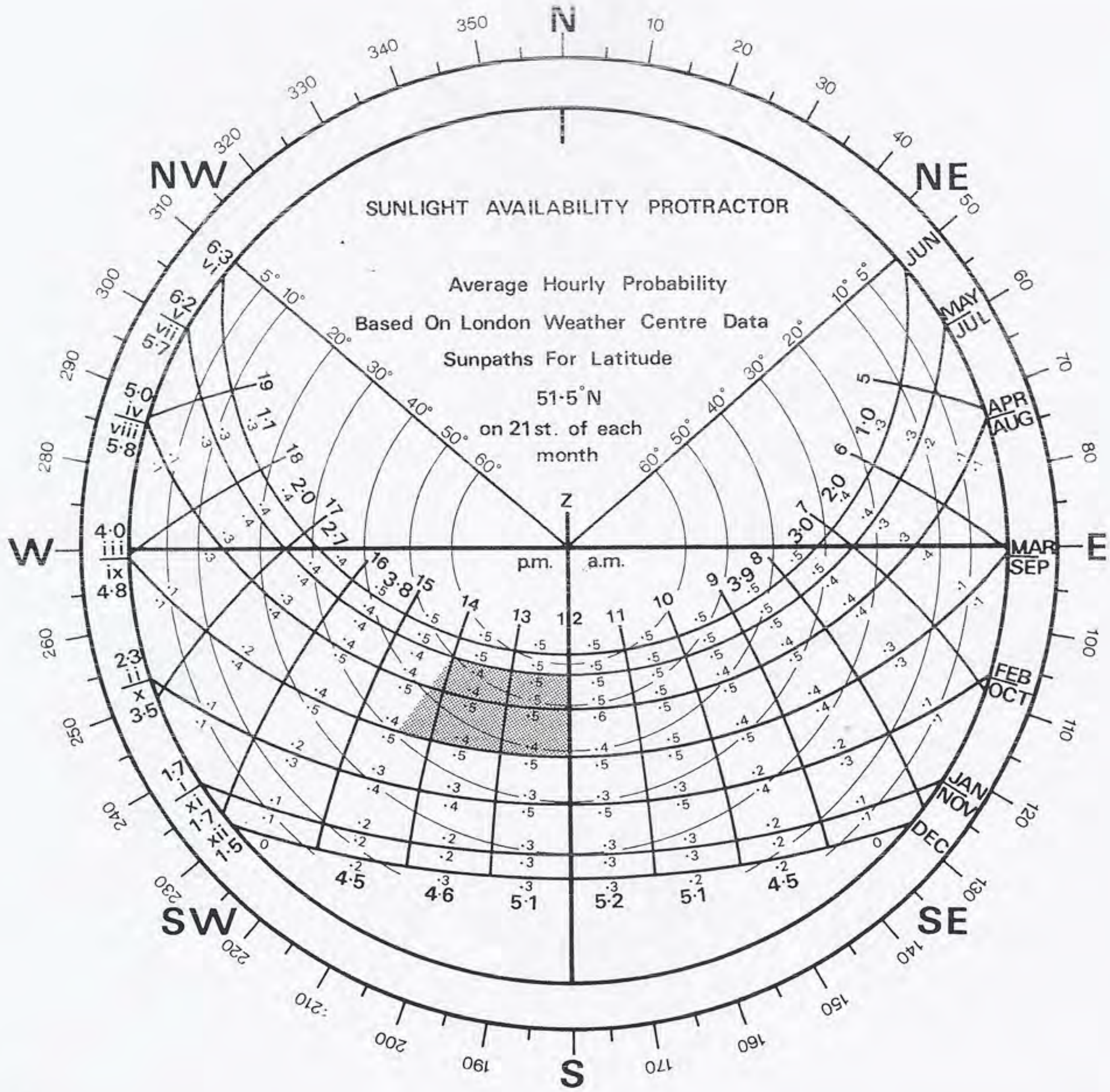
The method described above sounds complicated but in practice is quite easy to use. Equations 3 and 4 can be applied using a small programmable calculator. For preliminary design analysis calculations for the four corners of the building would be sufficient for use with the sunlight availability protractor or other sunpath diagram. Alternatively the entire procedure would lend itself to automation using a computer program, which would enable the analysis to be completed very quickly.

Of course the technique described in Section 4 can easily be adapted for use with vertically glazed reflective facades. In fact the method is simpler to apply because equations 1 and 2 can be used instead of the more complex equations 3 and 4.

For designs where solar dazzle has been identified as a potential problem, what can be done to alleviate its effects? At the initial design stage there is considerable scope for rectifying the situation. Aspects of site planning such as road layout can be altered; in general possible road approaches should be oriented parallel to the sloping facade on plan rather than perpendicular to it. Alternatively the geometry of the sloping facade itself may have to be altered. Initial experience suggests that, in Europe and the USA at least, the greatest problems occur with facades facing within 90° of due south, sloping back at angles between 5° and 30° to the vertical. Where the facade slopes at more than 40° to the vertical (less than 50° to the horizontal) solar reflections are likely to be less of a problem, unless nearby buildings are very high; and facades which slope forward, so that the top of the building forms an effective overhang, should also cause few problems in this respect. In the northern hemisphere, north facing facades should only cause reflected solar glare on a few occasions during the year, if at all.

Other solutions to the problem could include the provision of landscaping and trees, which may be the only answer in cases where the sloping facade and nearby buildings have already been constructed. In some cases landscaping will have to be quite extensive (perhaps around half the height of the sloping building) and this underlines the importance of carrying out the appropriate calculations at the design stage.

Of course equations 3 and 4 are not restricted to building facades but can be used to model reflection from any flat sloping mirror. For example, some forms of innovative daylighting system[8-10] incorporate tilted mirrors to direct sunlight and daylight into working areas of buildings. Equations 3 and 4 could be used to model the effects of these mirrors at different solar angles.



Note 1
The tinted area represents the sun position locus in Figure 4 plotted onto Sunlight Availability protractor

Note 2
For computation of total yearly sunny hours, multiply summated average figures from the protractor by 30.4 (average days per month)

Figure 5 BRE Sunlight Availability protractor

CONCLUSION

With the increasing use of mirrored glazing as an architectural resource, the evidence is that town planners are becoming aware of reflected solar dazzle as an environmental problem (see for example References 2, 5). The technique described in this paper should enable planners to objectively assess the risks of solar dazzle in each particular case, and to quantify its effects on motorists, pedestrians and occupants of adjacent buildings.

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