The pier and building of the European Solar Telescope (EST)

F.C.M. Bettonvil*[a], R. Codina[b], A. Gómez Merchán[c], R.H. Hammerschlag[a], J.J.M. Hartman[d], E. Hernández Suárez[e], A.P.L. Jägers[a], G. Murga Llano[c], J.W. Pelser[d], G. Sliepen[a]

[a]Astronomical Institute, Utrecht University Princetonplein NL-3584CC Utrecht, The Netherlands;
[b]Dept. de Resistència de Materials i Estructures a l'Enginyeria, Universitat Politècnica de Catalunya, Jordi Girona 1-3, Edifici C1. 08034 Barcelona, Spain;
[c]IDOM Ingeniería, Arquitectura y Consultoría, S.A., Área de Análisis y Diseño Avanzados, Avda. Lehendakari Aguirre, 3. 48014 Bilbao, Spain;
[d]Bouwstudio Pelser Hartman b.v., Veemarktkade 8, NL-5222AE 's-Hertogenbosch, The Netherlands;
[e]Instituto de Astrofísica de Canarias, Avda Vía Láctea S/N, La Laguna 38205, Tenerife, Spain.

ABSTRACT

EST (European Solar Telescope) is a 4-m class solar telescope, which is currently in the conceptual design phase. EST will be located in the Canary Islands and will aim at high spectral, spatial and temporal resolution observations in the photosphere and chromosphere, using a suite of instruments that can produce efficiently two-dimensional spectropolarimetric information of the thermal, dynamic and magnetic properties of the plasma over many scale heights.

The pier is defined as the construction that supports the telescope and the enclosure. It needs a certain height to minimize daytime ground turbulence. At the bottom of the pier a large instrument lab is located, 16 m in diameter and 10 m high. To the pier is attached a service building that accommodates all auxiliary services, possibly together with a separate building.

Solid concrete- and open framework piers and building structures are compared, in terms of stability, thermal properties and flow characteristics. FE models and CFD simulations are used to give qualitative insight in the differences between the alternatives. The preferred alternative is a cone shaped pier surrounded by an open framework.

Keywords: Telescope pier, building, solar telescope, CFD analysis, tower, local seeing, turbulence, kinetic energy.

1. INTRODUCTION

The EST (European Solar Telescope)[1] is a 4-m class solar telescope, which is currently in the conceptual design phase as a pan-European project involving 29 partners from 14 different countries. EST aims at high spectral, spatial and temporal resolution observations in the solar photosphere and chromosphere, using a suite of instruments (broad-band imagers, narrow-band tunable filter spectropolarimeters, grating spectropolarimeters), which together can efficiently produce two-dimensional spectropolarimetric information of the thermal, dynamic and magnetic properties of the plasma over many scale heights. EST will be located on the Canary Islands, at either La Palma or Tenerife.

The basic function of the pier is to connect the telescope/enclosure with the ground. Although in practice being part of the building construction, we treat the pier and building in this design study as separate subparts.

In this paper we will look at the requirements for the pier and building and analyze the different alternatives with help of Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD). We will look at the stability and thermal properties and conclude with a description of the baseline concept.

*F.C.M.Bettonvil@uu.nl; phone +31 30 2535218; fax+31 30 2535200

2. PIER DESIGN

2.1 Constraints

An important constraint for the design of the pier is the definition of the instrument (Coudé) room, which has a dimension of approximately 16x10 m (diameter x height). This has consequences for the design of the lower part of the pier (up to heights of ~15m). The pier is therefore divided into two parts: a lower pier part respectively an upper pier part. The lower part houses the instrument room; the upper part accommodates the transfer optics[2]. For the moment we leave open whether the instrument room will be located underground or not.
EST will get also an auxiliary telescope[3]. The concept of this telescope is 3 m long, 350 mm diameter, and aligned with the polar axis. The stability should be better than 1” and preferably mounted as high as possible. It should have an unobstructed field of view, and preferably outside the telescope enclosure.

The error budget specifies three values for the pier. The first is the budget for thermal aspects, and specified as a contribution of maximal 0.038” to image blur. The second is the budget for windshake, which is defined as 0.3” in tilt. Finally, the thermal stability should be better than 0.1”.

2.2 Alternatives

The main types were we have looked at are: solid piers (concrete, in cylindrical, rectangular, conical shape), open framework piers (made of steel, being transparent for wind), double piers (and internal pier, supporting the telescope, and an external pier, supporting the enclosure and blocking wind) and hybrid types, consisting of a concrete lower part and open framework upper part, as illustrated in Figure 1.

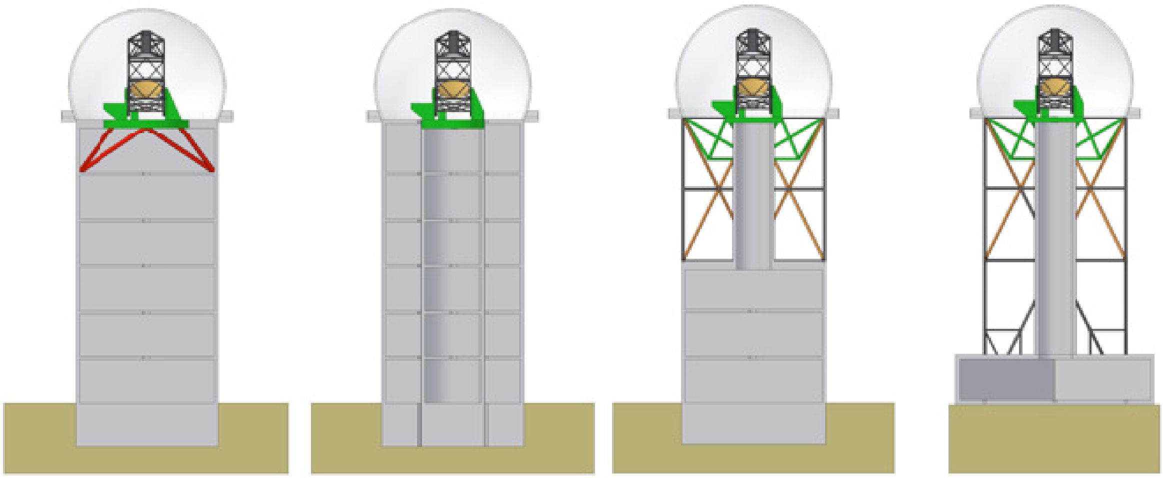

Figure 1. Pier alternatives as been suggested for EST. From left to right: Solid pier with common support of telescope and enclosure; Solid pier with separate support of telescope and enclosure; Solid pier lower part, transparent framework upper part; Transparent framework over full height. Scale and proportions in the sketches: the diameter of the primary mirror is 4.2m, the height of the tower is 40 m, the diameter is 20 m.

2.3 Pier height

Solar telescopes are always built on top of a tower, which helps in mitigating daytime ground-layer seeing, being most troublesome close to the ground. Awaiting results from the EST site characterization campaign[4,5], we have used here La Palma data from the ATST site test campaign[6], which resulted in values of the Fried parameter r_0 as function of height (Figure 2). Taking into account a r_0 of 6 cm as lowest useful seeing condition for Multi Conjugate Adaptive Optics (MCAO) operation, we find that at 8-, respectively 18- 28- and 38 m height, 13% of the data, respectively 26, 36 and 42% has seeing better than 6cm.
Also the number of excellent days (defined as r_0>15cm) increases as function of height, with respectively 1, 2, 3, 5% even steeper, as does the best r_0. The results show clearly that it is of great advantage to choose the highest pier possible, with the main consideration that also costs do increase due the larger construction costs (due to the increase in the tower

height as well as the required larger wall thickness for maintaining stiffness), but in relation to the total project costs, an increase from 28 to 38 m, is only a few percent.

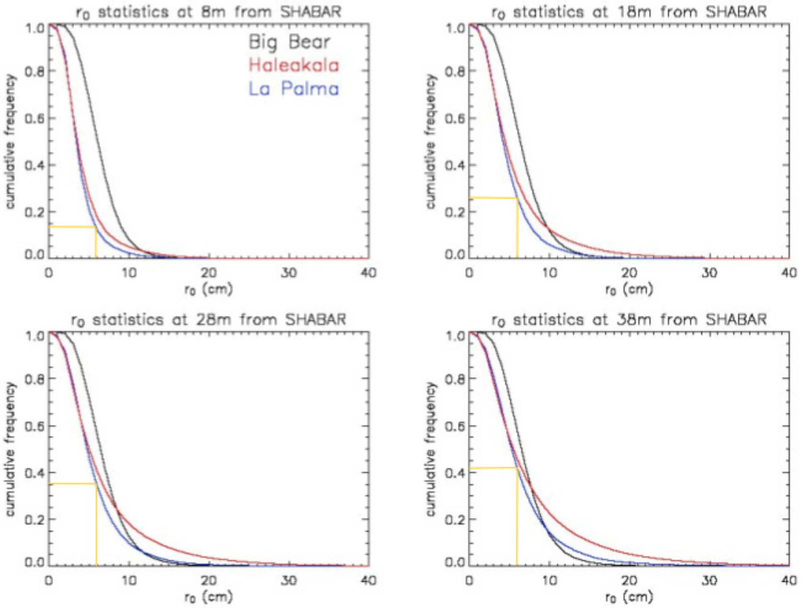

Figure 2. Cumulative frequencies of r_0 for heights of 8, 18, 28 and 38m as measured during the ATST site test campaign at three different locations [from (5)].

2.4 Stability

In order to get insight in the stability criteria, concepts of piers and foundation have been modeled and calculated with ANSYS. Figure 3 shows a selection. For all cases a wall thickness of 0.5 m, a diameter of 23 m and pier height of 30 m has been taken. Double piers consisted of a 'standard' single pier, surrounded by an additional construction, forming the outer pier. Also open framework towers have been studied[7]. An open framework pier has some differences compared to the concrete tower:

- it is made of steel instead of concrete,
- due to the open construction the wind buffeting is much lower,
- the framework design can be such that a parallel motion of the telescope platform occurs, in other words theoretically in first order no tilt is present.

For the open framework pier a base of 20 m was chosen, constructed from tubes of 244x10 mm (diameter x thickness).

The performance of the pier is considered to vary with the characteristics of the underground. For the volcanic mountaintops of La Palma and Tenerife the characteristics depend on the location where the telescope will be erected, and these can vary significantly. Typically the underground consist of loose lava gravel, interchanged with ridges of basalt that reach the surface occasionally. For our analysis we have used the ground analysis that has been carried out for GTC. We have simplified the underground with a model of a soft top layer (dynamical Young modulus 2030 MPa), which lies on top of a denser layer (5400 MPa) on a depth of 15 m. The ground has been modelled as a purely elastic material.

Two types of foundations have been considered:

- a (shallow) slab foundation, which in its simplest form is a concrete plate. It lays 1m deep and is in thickness equal to the wall thickness of the pier. The diameter is 2 m larger than the pier. It is able to counteract wind load due to its large surface.
- a deep foundation, which penetrates through the soft layer, into the stiffer underground. A deep foundation can be either a deep cellar, or pillars, drilled into the underground.

In the first analysis that has been done, no telescope or enclosure was modeled, and the wind load on the tower modeled as a horizontal pressure field (140 N/m^2 for 15 m/s wind) over the full height. The wind load values are conservative and about 50% higher than found with CFD.

Only static deformations have been computed being tilt and translation, and in addition the lowest eigenfrequencies.
In summary, overall, the tilt for all single piers is around 0.08", for and thus well below the requirements value. In general, for all piers, it seems that the stability is not critical, and much better than the expected stiffness of the telescope[8]. Of all single towers the cone tower behaves best, being twice better than a cylindrical pier or open framework pier. The 'step tower' consisting of two cylinders with different diameter, with the smaller one on top, is a negative exception and does with 0.25" just satisfy the requirements, which is due to the weak connection between the two halves. Piers consisting of an inner and outer tower, perform ideal since the inner tower is not exposed to wind and the underground is stiff. The coupling to the inner tower is very weak.
Piers standing on the soft layer, show 15-25% larger tilt when compared with a stiff underground. Comparison of deep and shallow foundations gives differences of 4% (in case of a soft underground) and 10% in case of a stiff underground. From this we conclude that the underground is not a real critical aspect.

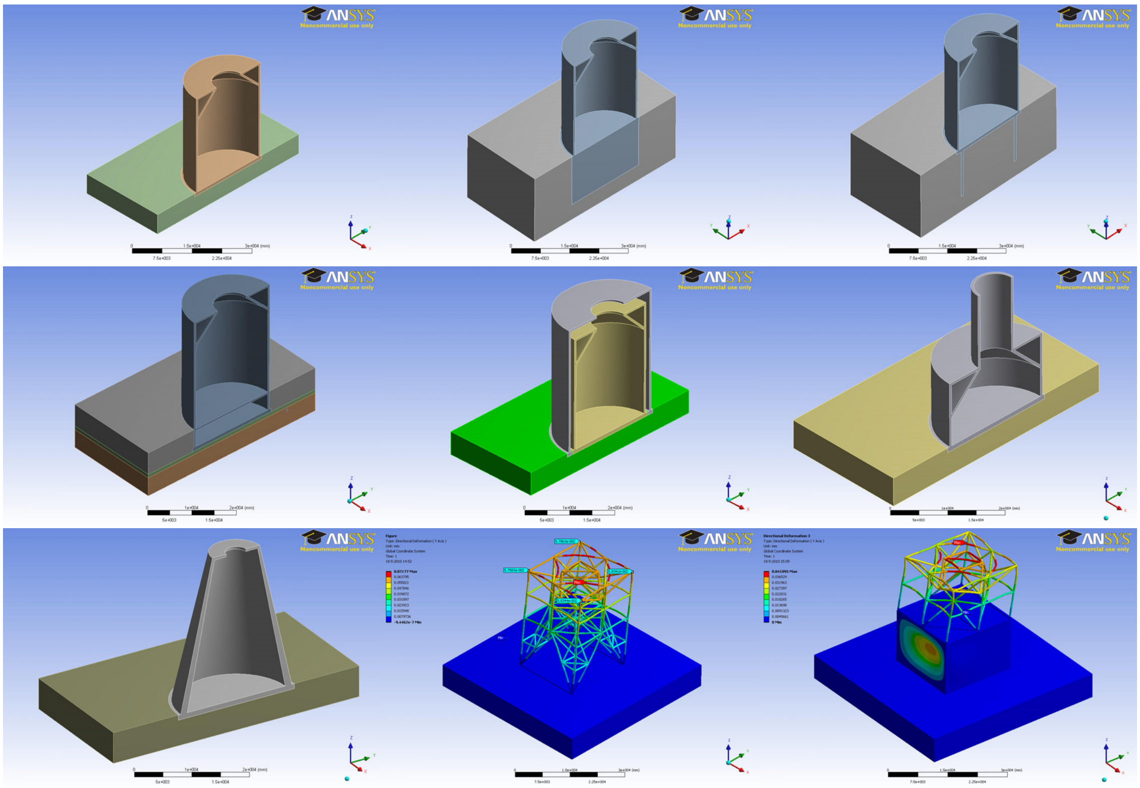

Figure 3. Some examples of analyzed pier shapes. From left to right, top down: 1. Single tower with shallow plate foundation; 2. Single tower with deep foundation; 3. Single with pole foundation. 4. Single tower with deep foundation on stiff underground; 5. Double tower with separated plate foundations; 6. Stepped tower with plate foundation; 7. Cone tower with plate foundation; 8. Open framework tower on plate foundation; 9. Hybrid tower on plate foundation.

Regarding horizontal deflection, no deflection larger than 0.056mm has been calculated, which seems low, but is not specified in the requirements.
Piers on a shallow plate foundation have their lowest eigenfrequency around 7.5 Hz (stiff underground), respectively 6.8 Hz (soft underground). There is no difference between single and double pier constructions, since the inner part of the double pier is identical to a single pier. Weakening of the inner pier, which would be permitted based on the tilt calculations, is not recommended because it will also bring the eigenfrequency down and always some wind buffeting will be present when a dome and/or telescope are placed on top. The cone pier has the highest eigenfrequency, being 14 Hz (stiff underground) and 12 Hz (soft underground). An open framework tower has its lowest eigenfrequency at 5.1Hz. A 15 m high DOT-style open framework tower gives 5.7Hz, both from simulations and measurements at the real tower[7]. Not modelled have been dampers, which have been used at the DOT, and are effective in limiting the resonance amplitude.

In the second analysis that was done, also an enclosure has been added, which increases the tilt with approximately a factor 2. Also, for the single pier the dynamic pier response has been studied for a wind field with velocity variation 50% with 15m/s mean velocity (also conservative, with variations being <30% in reality). This resulted in a pier tilt being 15% smaller then for the static calculations.

In conclusion, the results show that in the case of an open air configuration it is not useful to provide a double tower to isolate the telescope pier from the wind load, since the pier is much stiffer than the telescope. In the case of telescope enclosed in a dome, although the pier wind deformation is still limited, the double tower with independent foundation could be useful in order to avoid transmission of vibration from the dome to the telescope during the operation.

The results show too that the effect of wind on the pier is well within the requirements for the auxiliary telescope.

3. BUILDING

The building includes all necessary facilities and services required for telescope operations, support and maintenance. Among them are the control room, storage room, workshops, laboratories, coating facilities, offices, elevators and auxiliary equipment as power plants, water coolers and fire extinguishing equipment. Figure 4 shows the basic concepts for the building, being accommodated around the pier, attached to the pier, or separate from the pier.

The building should minimally disturb the natural seeing conditions. For this reason, all services that generate heat, pollution or vibration will be placed in an additional building placed in downwind direction at a certain distance from the telescope location. This building will be connected to the telescope building by means of a duct channel.

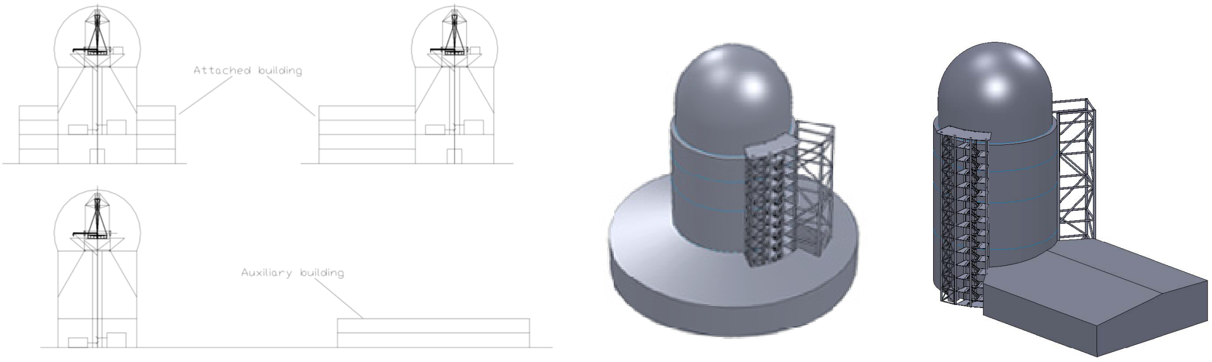

Figure 4. (Left) Three different concepts for the building: a) building around pier; b) box-shaped building attached to pier; c) separate building. (Right) 3D models of circular building and box-shaped building.

4. THERMAL ASPECTS

A dominating factor in the design of the pier (as well as the enclosure[9]) is the contribution to the seeing degradation. The contribution of the pier to the seeing error budget (in image size in arcsec) is set to 0.038" as described in Section 2.1. Seeing degradation occurs when a surface with a deviating temperature causes warm air bubbles to rise upwards, penetrating the optical beam. A first approximation can be made to estimate the effect of natural convection that occurs above a heated surface in the case there is also some wind[10].

The velocity of natural convection (along a vertical plate, empirically obtained) can be described with:

$$v_{nc} = 0.37 \cdot \frac{\beta \cdot \delta^2 \cdot g \cdot \Delta T}{4 \cdot \nu} \tag{1}$$

with β – volumetric thermal expansion coefficient, δ – boundary layer along the surface, g – earth's gravity acceleration, ΔT – temperature difference wall – air, ν – kinematic viscocity. For δ we can write:

$$\delta = 3.93 \cdot \mathrm{Pr}^{-1/2} \cdot (0.952 + \mathrm{Pr})^{1/4} \cdot Gr^{-1/4} \cdot L$$

(2)

with and Pr – Prandtl number (ratio kinematic viscosity and thermal diffusivity, being ~0.75 for air), Gr – Grashof number (ratio of buoyancy and viscous force) and L the characteristic length of the wall. The Grashof number we can calculate with:

$$Gr = \frac{g \cdot \beta \cdot \Delta T \cdot L^3}{v^2} \tag{3}$$

To estimate the height of the disturbed layer above the wall we make the assumption that at the time the air has travelled due to the wind from the edge towards the center of the pier, the convection travelled from the wall to the height H (Figure 5). We can write then:

$$L = \frac{v_{nc}}{v_{wind}} \cdot H \tag{4}$$

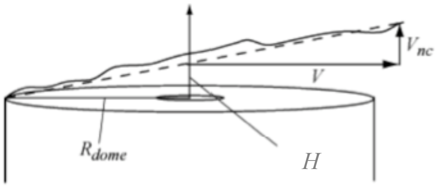

Figure 5:.Vector sum of wind velocity V_{wind} and natural convection V_{nc} to estimate the height of the boundary layer H in the center of the dome [from (9)].

When we look to the lower half of the pier and if we assume that the roof of the instrument room is 18.5 m below M1 (15 m height difference from instrument room to telescope platform + 3.5 m height difference between telescope platform and M1), and that the pier has a diameter of 20 m, we can calculate then that the difference in temperature may exceed 10˚C for wind of 2 m/s. For 1 m/s wind, 5 ˚C is allowed. The conclusion is that for the lower pier part convection is not likely to disturb the local seeing in the optical beam, since the air will not reach M1 (assumed that the building/pier does not disturb the flow pattern significantly by generating vertical wind flow patterns, see Section 5 for more details).

For the upper pier half the situation is different. Considering a solid pier of 30 m height, and based on the same relations, we can calculate that the convection velocity at 30 m height, with a temperature difference of 5˚C between wall and ambient air will be 5.7 m/s, which results with wind of 2 m/s always in disturbance of the optical path, which starts 3.5 m above the pier top. To avoid any heat in the optical beam, a convection velocity of no more than 0.8 m/s should be present, which is caused by a wall temperature difference of only 0.1˚C.

We can also estimate the seeing degradation of air in case that it would enter the optical path, based on the thickness of the boundary layer, which is with equation (2) at 30 m height around 8 cm thick for a $\Delta T_{wall-air}$ of 0.1˚C. Assuming that the buoyancy flow enters directly the optical path, which is indeed the case when the telescope is pointed at low elevation angles, it follows then that with a quadratic velocity profile for the temperature in this layer[11] $dT(y) = \Delta T_{wall-air}(1 - y/\delta)^2$, the average difference in temperature in the air is 0.03˚C. By assuming that this air plume is similar to the shell air plume in the slit of a dome, we may use Racine's relation[10], which gives then an image degradation of 0.001", which is neglectable. It follows that for reaching the error budget of 0.038" an air temperature difference of ~0.5˚C is allowed, and a pier temperature difference of ~1.5˚C.

For estimation of enclosure shell seeing, also a method originating from Ford[10,12] is being used, who calculated based on the shell temperature, boundary layer thickness, heat transfer coefficient and physical properties of air, the air temperature and converted that into a image blur by using Racine's relation. When using the same method but using equation (2) for layer thickness[11] and $h = 2 \cdot k / \delta$ (typical for vertical convection) instead, we obtain similar results as listed above.

The conclusion of the above is that a structure located many meters below the optical path, shows much relaxed temperature requirements. A roof 18.5 m below the telescope may differ 5˚C before *any* heat will reach the optical path, and thus no image degradation will occur at all. A pier which extends over the full height, has on the other hand the tendency to bring heat into the optical path, even at low winds speeds, due to the significant convection velocity that occurs at the top of the pier and the minimal height difference between the top of the pier and the optical path, but as long as the temperature difference between wall and air is smaller than 1.5˚C, it will cause image blur that is within the requirement of 0.038”. The air temperature in itself also varies during the day, with a typical span of 4-10 ˚C [9], which have to be taken into account.

The other thermal requirement is the expansion of the tower, which should result in tilt smaller than 0.1”. If we assume that the tilt is caused by (uniform) heating from one side, it requires in first approximation temperature differences in the order of 0.01 ˚C, which seems difficult to achieve.

Several alternatives have been considered to maintain the pier surface temperature within the requirements:
A) Active air suction, which uses a perforated skin around the pier through which air is sucked away between the plating and pier wall. This way, the air temperature of the perforated skin and air close to the skin could remain close to ambient air temperature. The method has been analyzed by ATST[13], and resulted in estimates of differences between wall temperature and ambient air of ~1˚C. About 100kW fan power is required and extensive infrastructure for air ducts.
B) Active liquid cooling, similar to the shell cooling of a dome with Thermplate[9]. It gives good performance, but at the price of being very complicated and costly. C) Passive, in which the concrete is used as a large heat integrator. Transient simulations[13] (including convection, conduction and radiation) showed that the concrete wall will maximal be 5˚C warmer or cooler than ambient air temperature (in early morning and late afternoon). D) By making the pier transparent for wind, the area that is exposed to solar illumination is minimized, and thus the thermal problem. It also ensures that convection plumes that rise up from ground or lower building are quickly bend down below the telescope. It is the most effective method in mitigating pier seeing[14]. E) A step further is to locate the instrument (Coudé) lab underground such that no building exists at all. No pier seeing is produced. F) Horizontal baffles or catwalks on the pier could help slowing down the upward motion of natural convection, although such shields are exposed to sunlight, themselves creating local seeing, in particular at large elevations of the Sun. It requires optimization.

5. CFD ANALYSIS

CFD analysis has been carried out to study the impact of the wind flow on pier and building. The main objective of these simulations was to capture the pressure distribution, velocity field and kinetic energy around the pier and building. Also forces and moments were calculated. Thermal aspects have however not been studied yet, and is planned for a near future follow-up analysis. For the calculations rather coarse meshes have been used, together with dissipative turbulence models (Smagorinsky with the largest value allowed for the constant of the model). All results are stationary.

The 3D model has been made such that the computational domain is large enough to ensure that their boundaries are placed far from the building pier model, such that the effect of the boundary is minimal. The discretized domain is a section of 200x800 m, with a height of 150 m (see Figure 6, left). The pier is positioned 130 m from the boundary in the direction of the wind. As such, each different wind direction, had its own computational volume to ensure that always the same distance from the boundaries occur. The wind speed was 10 m/s. In total 22 different models have been analyzed, each with 1 to 3 different wind directions. The number of elements varied between 1 and 4 million.

In order to estimate the amount of turbulence in the optical beam, the mean value of the kinetic energy has been calculated, for each simulated case, inside a column of air that represents the optical beam above M1, 5x5 m wide and 20 m long (Figure 6, right), by adding up the values of all nodes inside the volume and dividing by the number of nodes.
The amount of turbulence inside the column is a measure for the optical seeing we can expect (although turbulence in itself is not harmful if no temperature differences are present.) In this comparison we assume that the temperature differences are caused by the telescope and enclosure (in the building simulations in all cases being the same) and assume that the building itself, which is relatively far away, does not contribute to temperature differences, but only has influence on the flow pattern and thus on the amount of turbulence in the optical beam. Figure 7 and 8 show the in this paper investigated pier and building models; table 1 and 2 show the results.

The building concepts all have the same dome. Turbulence values vary between 0.151 and 0.307, a factor of 2. This variation occurs for a single building, but different wind directions, and shows the same trend for all rectangular building shapes: wind 180˚ gives the lowest value, wind 270˚ the highest value, and 0˚ and 90˚ in between. There is no significant difference between a tall, flat and no building. Comparison of the box building with the round building also leads to the conclusion that the turbulence is similar.

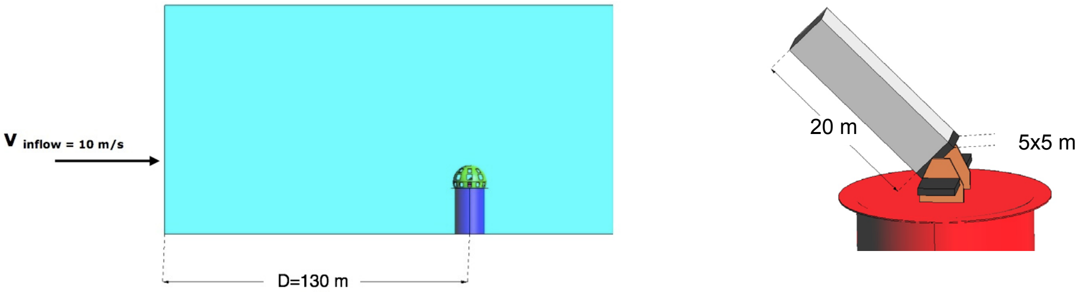

Figure 6. (Left) Dimensions of the computation domain are 800x200x150 m (wxdxh). (Right) The mean turbulence has been computed in a column of 5x5x20 m (wxdxL).

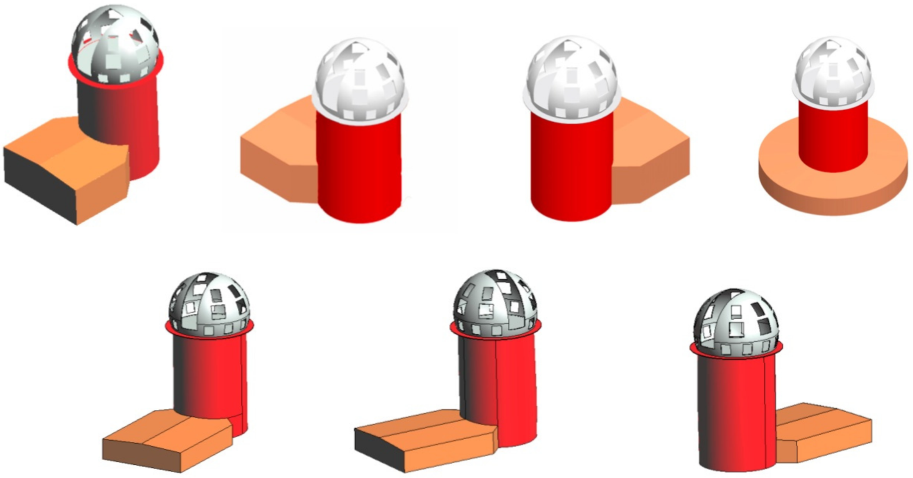

Figure 7. Investigated building models. From left to right, top to bottom: Rectangular building at 0˚ (Model 7); Rectangular building at 90˚ (Model 8); Rectangular building at 180˚ (Model 9); Round building (Model 10); Flat rectangular building 0˚ (Model 11); Flat rectangular building 90˚ (Model 12); Flat rectangular building 180˚ (Model 13).

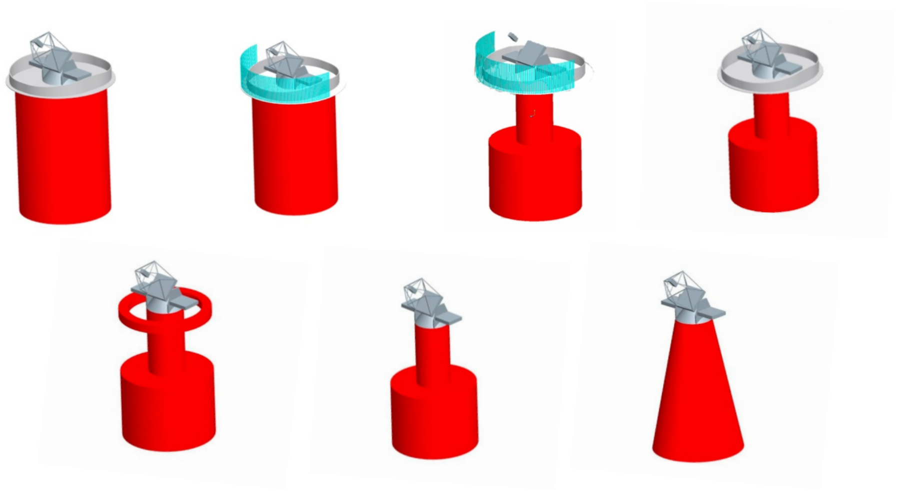

Figure 8. Investigated pier models. From left to right, top to bottom: Large cylindrical pier (Model 3); Large cylindrical pier with wind shield (Model 4); Small cylindrical pier with wind shield (Model 11n); Small cylindrical pier (Model 14); Small cylindrical pier with open floor (Model 18); Small cylindrical pier without platform (Model 19); Cone shaped pier (Model 20).

Table 1. Mean turbulence value for different building types and wind directions.

Model #	Building orientation	Wind dir.	Mean turbulence value
Model 5	No building	90°	2.52E-01
		180°	1.57E-01
Model 7	Rectangular building 0°	0°	2.18E-01
		90°	2.62E-01
Model 8	Rectangular building 90°	0°	2.10E-01
		90°	2.69E-01
		270°	2.86E-01
Model 9	Rectangular building 180°	0°	2.11E-01
		90°	3.07E-01
		180°	1.51E-01
Model 10	Round building	0°	1.96E-01
Model 11	Flat building 0°	0°	2.09E-01
		90°	2.99E-01
		180°	1.87E-01
Model 12	Flat building 90°	0°	2.12E-01
		90°	2.68E-01
		180°	1.74E-01
		270°	2.93E-01
Model 13	Flat building 180°	0°	2.07E-01
		90°	2.77E-01
		180°	1.76E-01

Table 2. Mean turbulence value for different pier types and wind directions.

Model #	Pier type	Wind dir.	Mean turbulence value
Model 3	Large cylindrical pier	0°	2.56E-01
		90°	2.14E-01
Model 4	large cyl. pier /w windshield	0°	2.37E-01
Model 11n	small cyl. pier /w windshield	0°	1.74E-01
Model 14	small cylindrical pier	0°	2.32E-01
Model 18	As model 14, /w open floor	0°	2.13E-01
Model 19	As model 14, no platform	0°	2.20E-01
Model 20	cone shaped pier	0°	2.18E-01

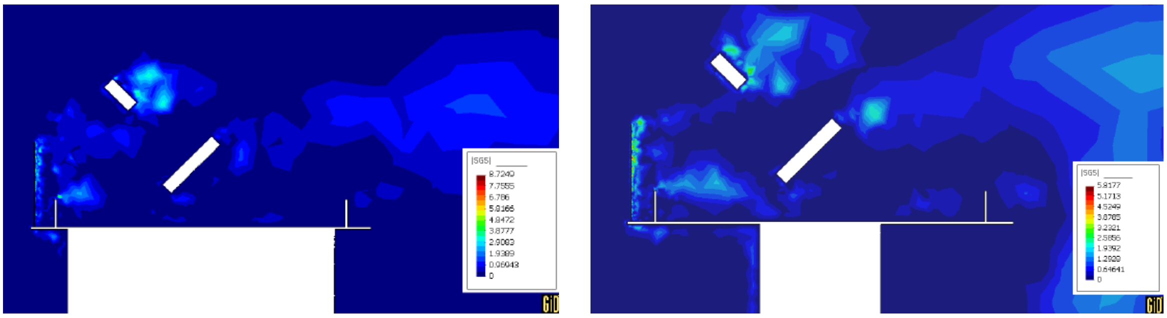

Figure 9. Kinetic energy field for retractable enclosure configuration with normal pier (left) and with reduced diameter pier (right). The kinetic energy is reduced for the case of the thinner pier. Note the different scaling, which is in the left picture at maximum 8.7, and in the right picture 5.8.

The differences between different pier shapes are more significant. Except for Model 18, the turbulence values for all models lay between 0.213 and 0.279, (30% variation). The large diameter pier with wind from the side appears worst, the small top pier with open platform best. Model 18 (small diameter top plus windscreen, Figure 9), behaves the very best, which can be explained due to the reduction in wind speed. We have to be careful however with concluding that this also leads to seeing improvements, since lower wind speed also could lead to larger temperature differences, due to the longer contact time of air with the surroundings. It needs to be verified by thermal modelling.

Comparing the configuration of a retractable enclosure with reduced pier diameter (model 11) with the configuration with normal pier diameter (model 4), gives a turbulence, which is 30% lower in the case of reduced diameter (Figure 9). Without windscreen the effect is less, but still 10%.

Apart from turbulence, flow patterns, as computed with CFD are studied too. From this, two conclusions were derived:
1) At the moment the horizontal wind flow reaches the pier top, some updraft occurs, which lifts up the wind flow about half the pier diameter. The volume just above the platform, is prone to turbulence and reduced wind speeds (Figure 10, left),
2) the wind flow that hits the pier, flows mainly around the pier in a horizontal plane, but there is also a slight vertical flow pattern: at the lower part of the pier a downward flow is visible, which can initiate a counter flow at the bottom area; at the top part a upward flow occurs. Apart from buoyancy, this is a second mechanism to transport air with deviating temperature up to the telescope (Figure 10, right).

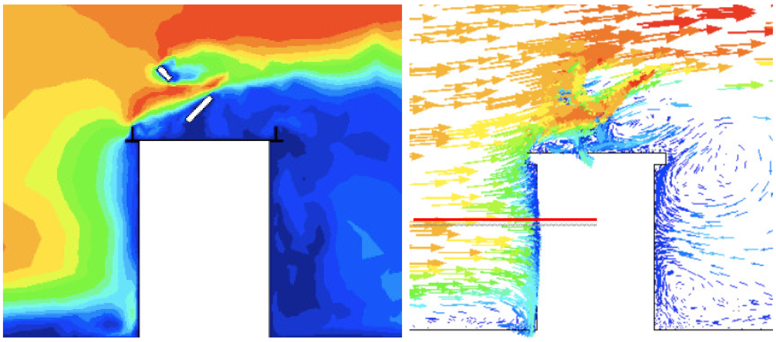

Figure 10. (Left) Illustration of wake and updraft on top of the platform, that lifts up the wind field and creates a low speed wind field associated with turbulence below; (Right) Wind field on the pier. The red line indicates the change of sign of vertical movement. Below the line there is a downward trend, above a upward trend. Especially the latter should be avoides since it transports air coming from the pier towards the optical path.

6. CONCEPT & CONCLUSIONS

The proposed concept for the pier is a tower with reduced diameter of the top (Figure 11). It minimizes seeing created by the pier, minimizes wind flow updraft, and helps minimizing the wake on the platform. A smaller top has no influence on the stability of the pier and the diameter of the pier could be smaller than what is required for the enclosure. The size of the transfer optics defines the minimum dimensions. No preferences are made for the type of foundation.
The lower part could be of concrete with conical shape towards the top, supporting the telescope base in a stiff way at the top. The concrete tower allows enclosing at the same time the instruments laboratory and the transfer optics.
A steel framework can support the enclosure and telescope platform. It is the best way of reducing pier seeing. This framework itself could get considerable stiffness[7], as analyzed in Section 4, and could be of help in gaining stiffness (in particular tilt) for the telescope. The auxiliary telescope can be accommodated in the framework.
The proposed height of the tower is between 30 and 40 m, which mean that the primary mirror will be placed between 35m and 45m high. The final height and detailed shape will be selected depending of the arrangement of the optical design, distribution of transfer optics and instrument laboratory and the rest of the facilities. Then also a decision will be made to locate the instrument lab underground or not.

Considering the concept for the telescope pier as a tower and containing the instrument room in its base, the preference is to attach the building to the pier, with some of the facilities housed inside the pier (Figure 12). There is no indication from the CFD analysis (Section 5) that the building has negative impact on the generated turbulence.

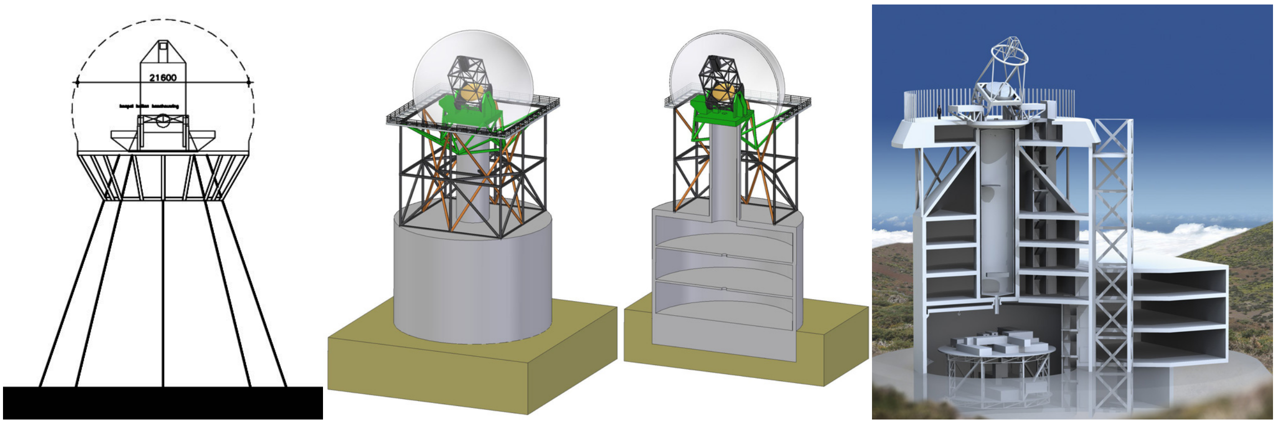

Figure 11. Concepts for the pier. (Left) cone shaped; (Center), cylindrical lower part, open framworwk upper part; (Right) current baseline concept.

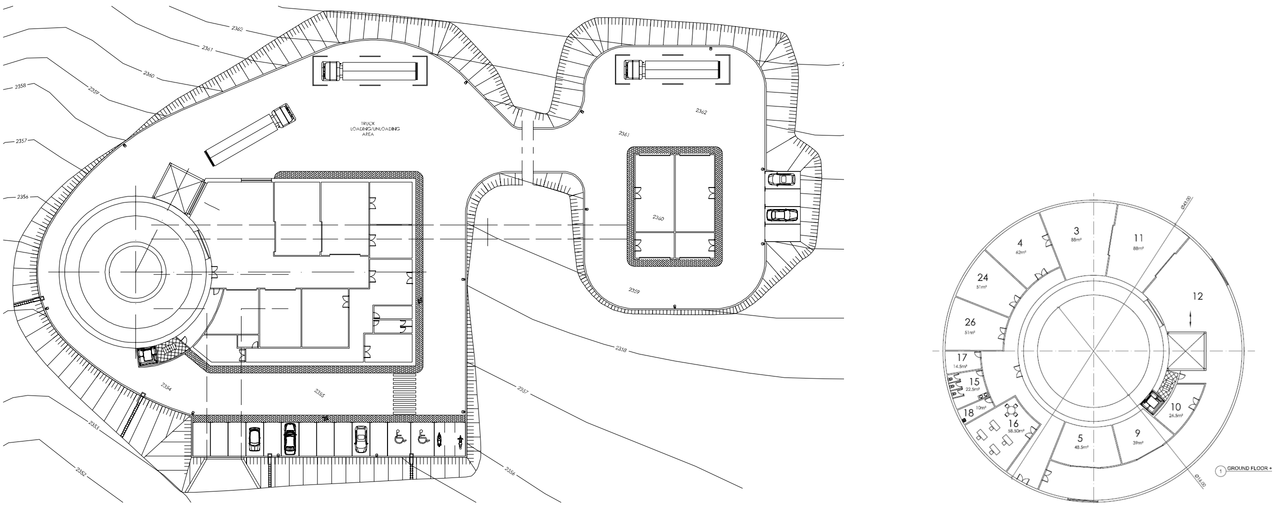

Figure 12. (Left) Conceptual building layout for EST with rectangular building; (Right) layout for round building.

The building distributed around the pier provides a layout where all the workshops, control rooms and staff areas are located next to the telescope pier, minimizing the required distances to the instrument room and telescope chamber from the building for the services and personnel access. This solution implies a unique ground floor with a circular distribution corridor around the pier. This corridor should have access to all the service areas and to the telescope pier itself. This kind of construction is not optimum in terms of surface utility. The need for a circular distribution corridor has a negative impact in the ratio between useful to total surface and.

The box-shape building attached to one side of the pier provides more efficient use of the total surface. This alternative allows using more common industrial-like structural constructions, which should lead to a minimum cost. The layout of the different services in a box-shaped building could be done either in a 1-storey or 2-storey building.

Two alternatives are considered for the building structure: steel structure and concrete structure. The steel structure is extensively used in industrial installations due to economical reasons and due to its flexibility to adapt different load supporting areas up to large spans with the same structural solutions. The main drawback of the steel structure is mostly related to the fire resistance. In typical industrial applications, resistances of 30 or 60 minutes are usually required. This is commonly achieved by covering the steel members with a layer of fire protecting paint. In applications different from industrial, such as residential or commercial, it is usually required to provide fire resistances of more than 60 minutes. In

such cases, the need for a special fire protection based on vermiculite projection is required, and the related costs rise significantly.
Concrete structures are the main alternative to steel structures in building construction. Under certain circumstances they may become a cheaper and a recommendable solution. In general, concrete is preferred in structures with a medium span (6-9 meters) and when the fire protection (more than 90 minutes of fire resistance required) of the structure is a major concern. Since the baseline for the telescope pier is a concrete structure, the concrete structure for the building can be also considered in order to build both at the same time. Both structures are considered feasible for the proposed building layouts.

The pier should provide three main access possibilities: stairs, a personnel elevator and a lifting platform with a load capacity of at least 13 tons for periodical removal of M1. Due to the pier layout, there is not much space in the interior to install these. Likely, the lifting platform must be placed outside the pier cylinder, as external structure. In order to minimize the possible turbulence generation, this structure is also proposed as an open framework. A crane will be located on the platform for lifting heavy material.

ACKNOWLEDGMENTS

This work is carried out as a part of the Collaborative Project "EST: The large-aperture European Solar Telescope", Design Study, funded by the European Commission's 7th Framework Programme under grant agreement no. 212482. EST is an ambitious project to build a 4-m class solar telescope, to be erected in the Canary Islands. The project is promoted by the Association for Solar Telescopes (EAST), formed by 15 research institutions from Austria, Croatia, Czech Republic, France, Germany, Great Britain, Hungary, Italy, The Netherlands, Norway, Poland, Slovakia, Spain, Sweden and Switzerland.

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