

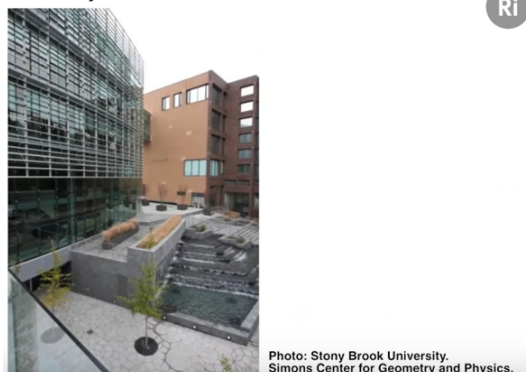
Forbidden symmetries

SIR ROGER PENROSE

(Last 20 minutes at the end of the talk)

Let's move on.

Stony Brook tiles



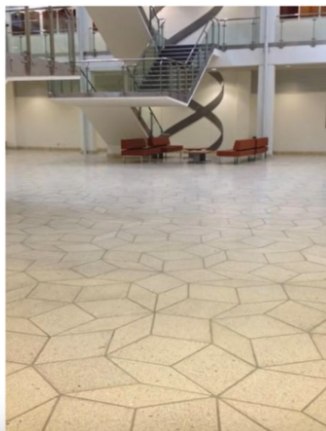
This is in Stoneybrook, the Simon Center I think it's called, it's an institute and on the ground, you'll see here, so we're going to go here first.



Transcription par Denise Vella-Chemla, octobre 2022, de la vidéo *Forbidden crystal symmetry in mathematics and architecture* visionnable ici : <https://www.youtube-nocookie.com/embed/th3YMEamzmw>, Royal Institution (RI) Event, 2013.

Here we have the straightforward rhombuses, no adornments, just rhombuses and here we have a view, it looks quite nice, nicely done again,. But the two kinds are both the same so you have to know what you're doing to see what the pattern is all about but you see regions of five-fold symmetry such as up here, and so on, in that region of five-fold symmetry. It extends to somewhere beyond it to so to do that for a while and then something else comes along.

University of Western
Australia, Perth.



Yes this now is the chemistry department floor in the University of Western Australia. And this is a really big area. I went up high to look down and see if I could see any mistakes. I didn't spot any which was fortunate. I think it's probably correct, yes, I had quite a good look at it, and I think it's correctly tiled. But you do find sometimes mistakes in these things. And there, you get some feeling for the size of it because somebody standing there on top of it.



Now the two tiles are not distinguished in the nature, but only in their shape and size.

Carleton College



Now that's a different one, these are kites and darts, that's Carleton University, and this is kites and darts nicely colored, nicely arranged all right there, how good shot of them, I'm not quite sure what that color coding is doing but it's interesting, it looks nice.

Carleton College

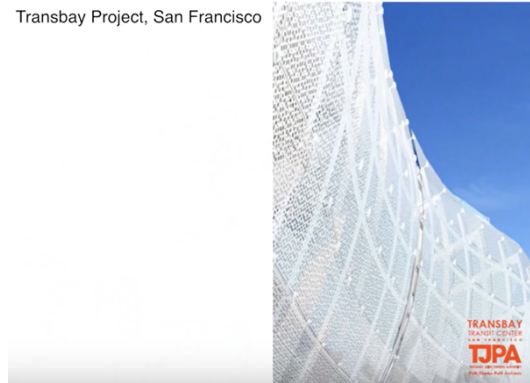


Indian Institute
of Information Technology,
Allahabad - interior of library



Now this is a place in India, Allahabad, where they have a big complex of buildings, and it's supposed to be this cope, the arrangements of the buildings and the designs of the building is all supposed to be based on a big version of one of these tilings. And I wanted to get an aerial view of this complex of buildings and I want Google map I had a look and I could just about see while some of those had some vague relation to the pattern. And I suspect they didn't finish or they tried to do it one way, and then did it a different way. I have no idea but it was hard to see the new patterns in the large being constructed according one of these tilings but maybe they are. On the other hand you see in the building here, there is a kite and dart pattern which seems to be pretty accurately done. The building itself is a 10 sided building and that sort of reflects the 10-sidedness that you've seen in this pattern in the middle. So this looks quite nicely done as far as I can see. I couldn't give terribly good pictures of these things to see what was going on there.

Transbay Project, San Francisco



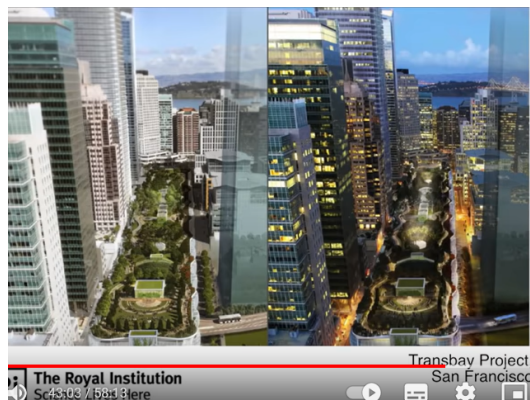
Now here's something else. Everything I've shown you up to this point is real.

I want to show you a project, this is a project for a thing called the Transbay, a transit area which is a railway Center in San Francisco. Now you don't associate railways with the United States but it's I think that's the idea is that railways should become more important. It was a big project and it was advertised and this particular company seemed to have won the work with this particular design. Now I want to show you some pictures of it,

Transbay Project, San Francisco



just to give you some feeling of the scale. This is inside, the trains will be underneath, and this is just to give you some picture, all these things, I say, are not real, they're simulations, but the intention is that this will become reality in some time. I forget they gave me some kind of a date whether I'm supposed to believe it, I'm not quite sure but it was I think it was a 2017, which doesn't sound all that distant in the future. I'm not sure that the tilings on the ground or anything to do with these tilings. But that's giving you a picture of the scale.



This also even more, on the top of this Transit Center, will be a park. So this, on the left, is the park in the day, this, on the right, is the same park at night. Of course, as I say, none of this is real, it's real in the future, I suppose that's the idea, but it's a simulation. But it looks wonderful, you have this wonderful park, in the middle of San Francisco set up above the ground level which is down here and down there and huge buildings which extend up and here it is at night.



Now this is what the sort of size on top of this is that Park then you see that area that we just looked at before with the people walking around and then there is a skin being here which wobbles around and underneath that would be the railway station that would be the last thing to get me off. I suppose that's a big project to get the railways you've got to put them right across the states but you will see if you look carefully at the cover that they views.

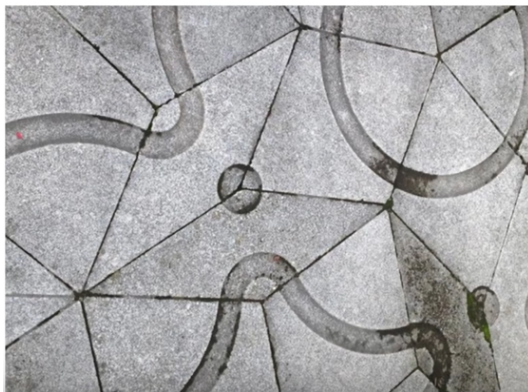


Now it's not flat which presents curious problems ; here you see more clearly : they have these panels, and they have the rhombus tiling on the panels. Now the reason they did this apparently is that if they chose a regular tiling, then when they joined the panels together you saw that they didn't match and it was looked dreadful, so they thought it would be good idea to use these tiles where you wouldn't know what was happening anyway (*Big laughs*) and so you wouldn't spot that they didn't match along the edges of course. And then they said well this is a nice seamless construction and the architects came across and visited me in Oxford, normal, they were very delightful people and I said well it doesn't quite match, does it ? And he said well yes we know that, but thought it doesn't matter too much, so I said well there are two things you can do here now you see it's not flat that was their problem and so you have to have a curved surface intrinsically curved surface, and you want to have a tiling which actually works on a curved surface. And so they thought, they fiddle it in this way. So I said well actually you could make it so that it matches well you see they have these seams here between them okay those aren't supposed to match because the things might expand and contract and then you won't have a gap here. However all these other ones are supposed to match so I say well you can do it if you don't mind slight changes in the size. So you can have a conformal map which means that locally they are the right shape, but the sizes can

vary just slightly. And they said we'll do it so that's what they're going to do, I think.

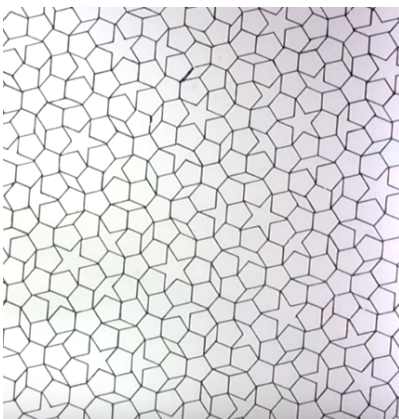
Now the last thing here I want to show you, coming back to real now.

Wadham College, University of Oxford

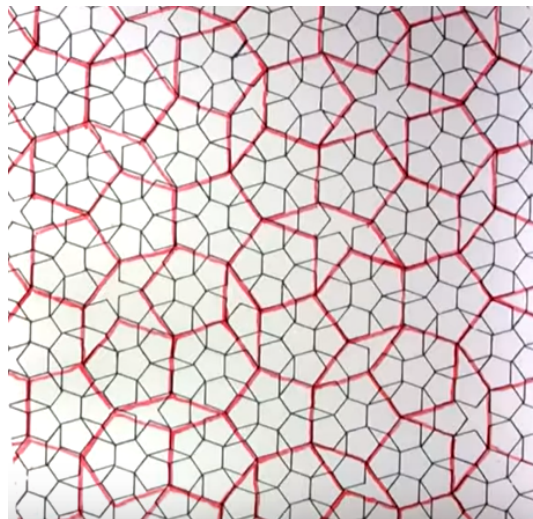


This is real tilings that we have at Wadham college, my college, and these are straightforward rhombuses but you see I insisted on having something which tells you whether you match them correctly. So you have these ; they're two style shapes, the fat one and the thin one, and every fat one is marked the same way and every thin one is marked the same way and you've got to match them. And then you get these non-periodic patterns. Well I've been far from the place they were laying these things. I've been to a play with my wife, and we came home London, so they were doing these tiles. And when I see how they're getting on, they were pretty well done, I wouldn't have a look, it looked very nice but I had a somewhat uneasy feeling so I went up on a little higher level, I looked down on it, I had even more of an uneasy feeling. I could quite place what it was and then I looked right over up the edge the builders had put an extra tile and they could see it would fit another one would fit just at the edge it would match perfectly and it would fit but if you put that tile in somewhere in the middle of the lawn, the thing would go wrong, it wouldn't go and we weren't having that (*Big laughs*) so they had to pull it out even though the lawn of course is a lawn and you don't see this pattern. Anyway this goes. It gives you one version of how to mark tiles but I thought, since we're having this new building, this wonderful new really isn't impressive new building, I'm not saying, and may we're going to have one of these tilings that there and I thought well well let's have something different so I'm going to show you something different.

Let's go back to this original tiling, go back to this.

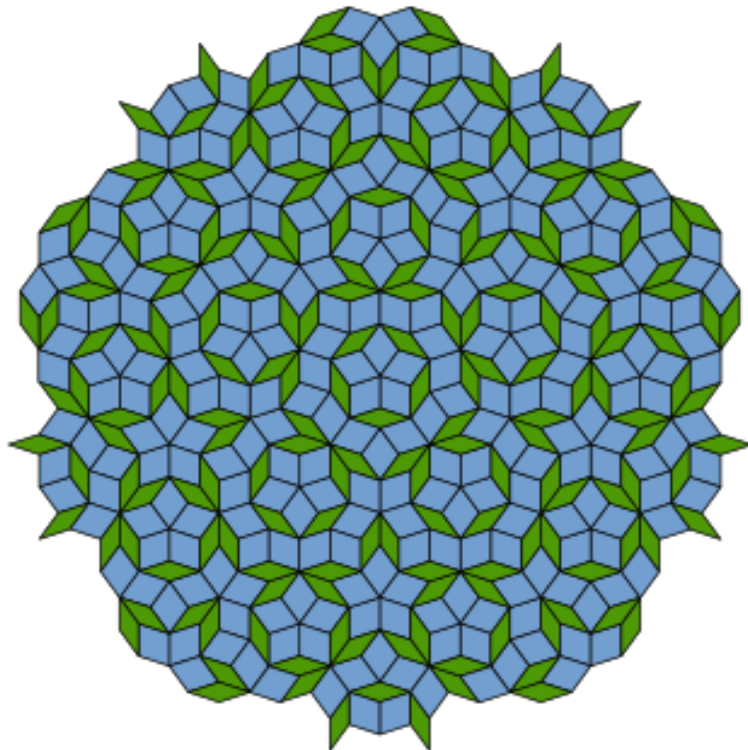


I pointed out that we did have in this pattern lots of these nice little decagons and then rings and pentagons around it. Now suppose you take those decagons, well, let's do it a little bigger, here we go, that's it, it's here, it's transparent and it's just the same color, I can't see it on the table, that's it here, we have it. That's the next version, it's the same thing you've got these little decagons and there's a big decagon, you see, and there we have the little, remember we had this ring of pentagons, you also sometimes get a ring, a bigger ring appendages here we have you know pentagons rhombus spending and rhombus big and rhombus all the way around and that's the sort of feature you get now, when you go to the bigger version of pentagons in the hierarchy. this you see a bigger decagon here and then you hear my ring of pentagons around it.



Okay so we get these rings and I thought would be nice to have those rings featuring I'm going to take this one off make it clearer so I've got to mark all those rings and I'm going to put have to do it the right way up this thing up that's it those rings just slightly further out for a reason which well let's say it makes it look a little nicer what I want to do but there's a mathematical reason to okay those are the rings I want undone I just drawn these rings in where you have them just outside the decagon and going around the pentagon's okay now the trouble is that if I try to mark those on these tiles they're not all marked the same way so I've got to have a few more I've got a few more arcs to make this now I'm going to mark this the same way around yes that's it I put these two together what do we see now well we see a sort of fattened out version of this Pentagon tiling etc remember we've got Pentagon's with a lock funny shapes there are Pentagon's there's a Pentagon there we have a funny shape one there's another Pentagon and here we have a justice cap you see but sort of squashed funny way and here we have the rhombuses and here we have the pentacle so it's the same pattern as before but sort of swelled out in funny ways okay now I need to fill that out just a bit more to make it well I think it's best if I put the rhombus pattern on there which is here then I can't find remember it's um underlies this pattern and you see that every rhombus has the same design pattern on it so if you marked the rhombuses in that way so that the thin ones just have two little circular arcs and the fat ones have two circular arcs across each other intersect it's the same everywhere you just need two kinds of tiles marked in this way and then you will see this pattern of circular lines coming out at you and I thought it would be rather nice in fact there was something a bit fortuitous about it because either you see the pattern in such a way that the rhombuses are quite obvious I didn't want that I wanted it so you didn't see it rhombuses very well and you saw that pattern which I rather liked and it's a bit surprising that you get that quite subtle pattern coming out from just two basic shapes and I done this what they have these are made out of granite I should say the tiles and the arcs are inlaid stainless steel so it should look rather impressive when it's finished now they had some samples of this in front of the old mathematics building like being in Edinburgh and I kept came back late on the train and I have a look at these things but wasn't very late was quite light and I looked at the tiles and the tower to Charles look completely different fat and the thin rhombuses look quite different I didn't want that and the circular arcs didn't fit together they looked horrible well the reason they didn't fit together

if it was a sunny day and they'd be they'd been what I call combed and that means that the light hits them in a certain direction and then it shines at you but if you're not in that particular direction then they look dark so that if the tiles are oriented differently then the arcs will of dark tile are a dark arc will join onto a light arc and you lose the pattern completely so I thought that looks dreadful as you as you look at the you just see the rhombus instead of the pattern well they said the solution to the combing problem is don't comb it so they do what's called polishing it instead and that's not directional so that should work I hope the other thing is the fact that the tiles look completely different I came back a couple of days later and looked at them again and then they looked exactly the same I thought what that's going on all these different tiles have they gone back to China to get new Granite's from no it occurred to me the difference was the first day it had been wet have been raining and the surface texture and the type of granite is slightly different and when it's red wet they look quite different when it's dry they look the same so this is wonderful it gives you a new perspective on the wet day the pout you see one pattern on a dry day you look at it and see a different pattern so I thought that's quite nice okay let's get back to the to the to the PowerPoint please well this is actually when the architects were trying to work out the the design it is just showing the pattern that's all this is doing here you see the arcs are in red they said don't worry it won't be red it will be in stainless steel and the tiles look quite different don't worry they won't look that different but it is quite useful to see this pattern because you can see this doesn't you can't see it so well but there is a sort of central point here and there we have a circle you see that's one of the many circles you've got circle illumise and just outside that you see this bigger floral arrangement now you see lots of those all over the place there's right round the edge you see there it's therefore all the way around there's one there's one there's one there's one so we wanted to have this in the center and this so that the tiles are such a size that you could actually see these other ones there are other ones right further into there's another one there so there's lots of these bigger rings oh thank you very much yeah I use the green one it works here especially on red here so here we see the that floral arrangement then we have bigger ones like that one here I thought it might be quite nice because mathematicians children could come and and walk along the the patterns you see if they get back to where they started some of them do some take a mints to the little of off the edge some way I think there's a nice theorem waiting to tell whether how many different kinds of patterns that are before they close up so it's nice to look at and that's the idea okay perhaps we could go back now oh no sorry I don't go back to any area so this is the latest not quite the latest but almost the latest they've done a little bit not quite finished in top pop there and things not quite finished there and some area here which is I finished which you can't see I think it's quite yes now this is a wet passage pest I think that's been wet yes because you see the difference in the tiles there the other one I think was probably quite dry see so there you can't very easily see the difference in the time this one shows the stainless steel it does seem to show up very nice nothing so this is that the white is just some cover that they put over top of the famous tomb they don't want to take them off until I think till the official opening and then you will see the actual stainless steel and how they join now so I think it should look pretty impressive at the last month I know here we have the view that's the entrance the main actress the building it's a stunning building and they say and it's all partly the design was geared so that the Radcliffe Observatory which is a very wonderful building which is sort of revealed night was all hidden by all sorts of other buildings previously and not only can you sort of see it when you get further back you could see the top much more clearly on the other side of the building you could see it very clearly and from the common room you see they designed it so that the building is in two halves here with a connecting room which is entirely transparent so that you sort of could see through it but it's a really a wonderful common room in there where you could sit down you have a beautiful view of the Radcliffe Observatory at the back and and you can see the tiling from the other side so let's know soon anyway I think that's the end of it thank you very much



4 dessins superbes de Penrose illustrant des passages de ses conférences :

