Quarry Management

Stages of downsizing rock

- *property location and relationship to neighbours*
- *rock mass properties versus potential aggregate quality and waste percentage*
- *pit planning and design*

- *inpit operations*
  - *drilling*
  - *blasting*
  - *loading*
  - *hauling*
- *fleet maintenance*
- *safety issues*
  - *dust & noise*
  - *flyrock*
  - *airblast*
  - *ground vibrations*
  - *accidents*

- *crushing, shaping and screening operations*
- *mobile versus stationary crusher plants*
- *dispatching end-products*
- *end-product cost, quality and pricing*

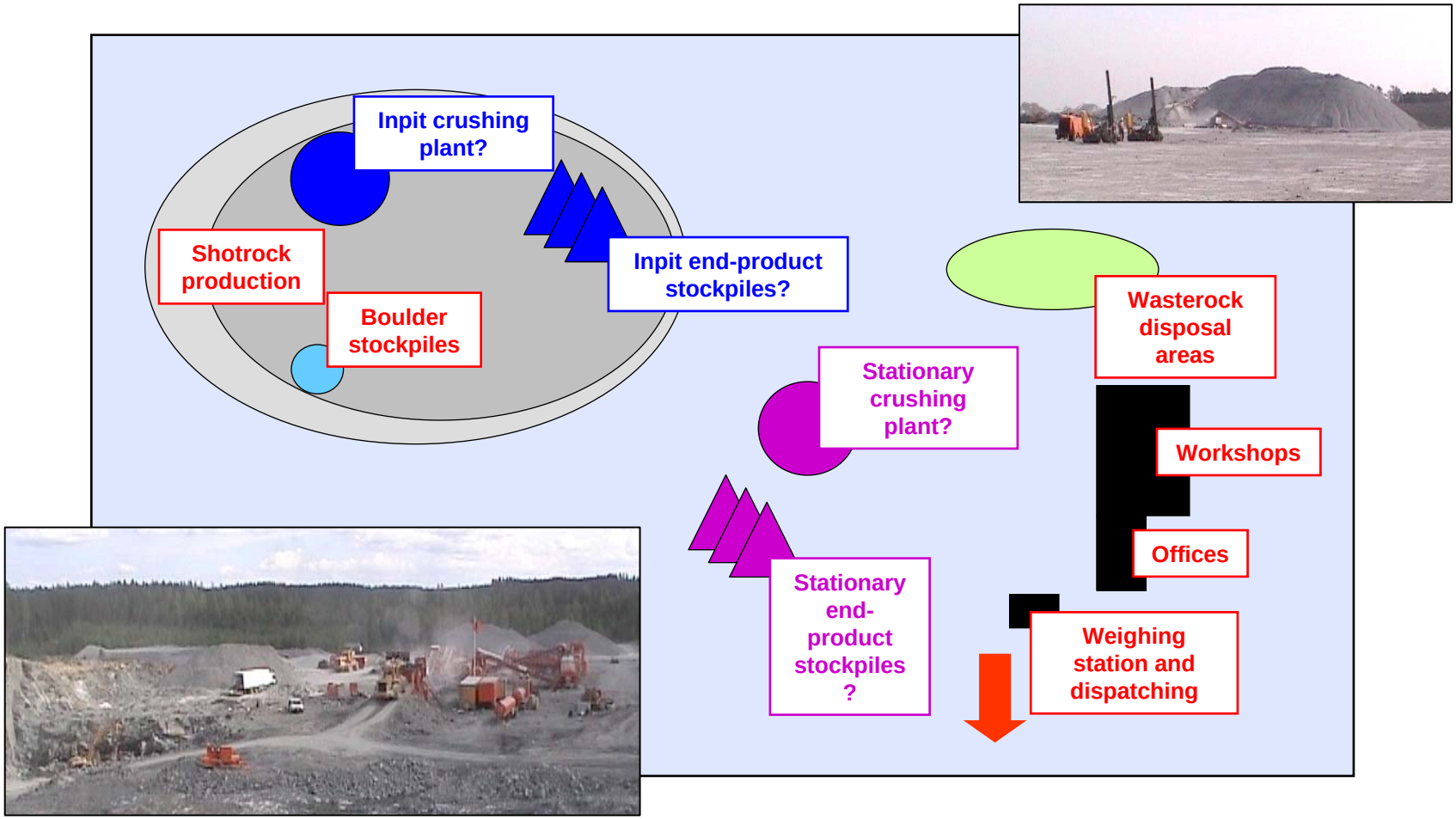
Quarry Management

Stages in the life of a quarry

- *market studies of aggregate requirements and price levels*
- *exploration and feaseability studies*
  - *geological mapping and terrain modelling*
  - *technology assessment and profitability analysis*
- *planning and development*
  - *mining rights*
  - *permits, Environmental Impact Statements, encroaching urbanisation, ...*
  - *financing*
  - *construction of plants, selection of equipment and transport systems, …*
  - *development for exploitation (roads, opening benches and ramps, drainage, shafts, …)*
- *exploitation*
  - *inpit production*
  - *processing and dispatching*
- *decommissioning and reclamation*
  - *restoring the quarrying area to an acceptable state of safety & environmental condition*

Quarry Management

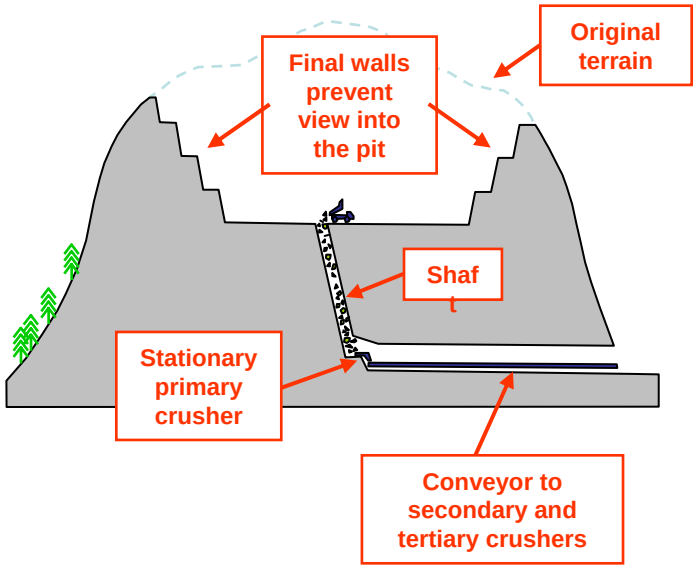
General quarry and pit layout alternatives



Quarry Management

Quarry and pit layout solutions

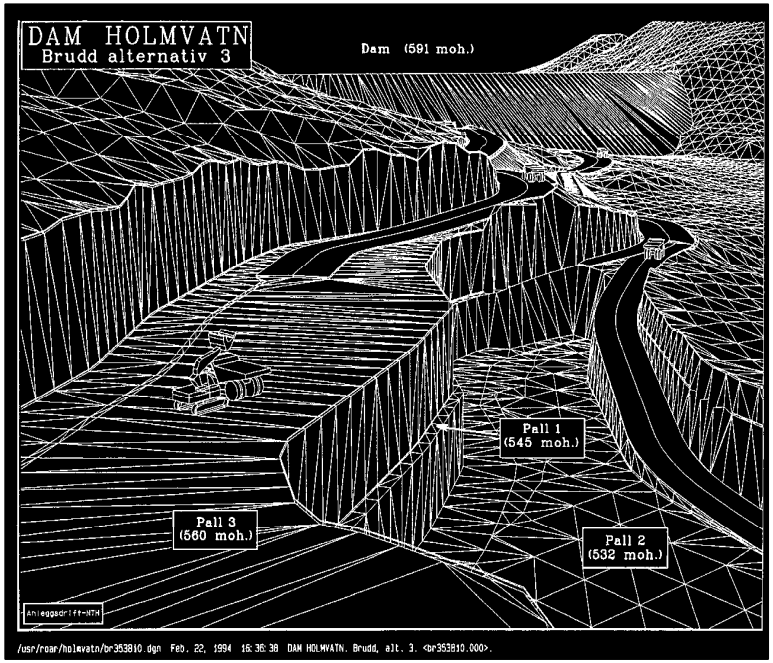
- *mountain tops*
- *mountain slopes*
- *developing industrial estates*
- *flat terrain*
- *UG quarries in urban areas*



Quarry Management

Pit planning and design

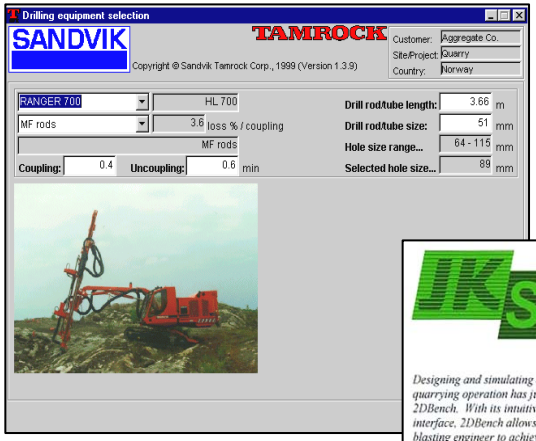
- *3D CAD capability for bench excavation scheduling and computation of volumes*
- *bench, roadway, dam and water-table, tip or stockpile localization*
- *overall quarry drainage design*
- *combined 3D CAD and aerial photography visualisation of pit, roadways or rockfill dam*

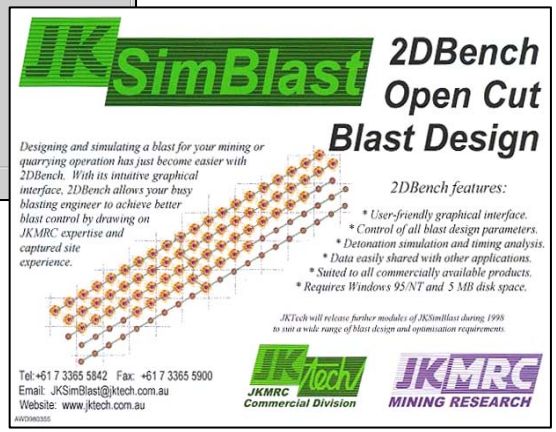


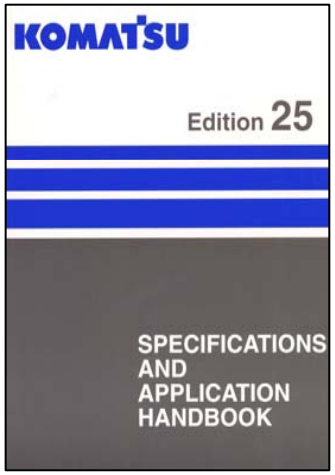
Quarry Management

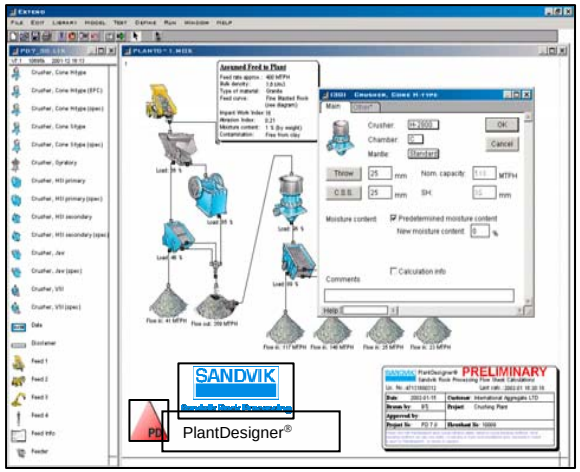
Quarry process planning and equipment selection tools

- *pit slope stability*
- *drilling operations*
- *blasting operations*
- *loading and hauling operations*
- *crushing and screening operations*
- *stockpiling*
- *dispatching and transport*









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Quarry Management

Today's enabling technologies for operations optimization

Pit planning and layout

- 3D terrain modelling
- geological mapping

Pre-blast

- marking of drill patterns or GPS guided feed collar positioning device
- measurement-while-drilling, MWD
- sampling of cuttings
- 3D drill patterns - by combining laser scanning of highwalls and drill-hole deviation measurements
- actual charge weight per hole

During blast

- velocity of detonation, VOD
- high speed videos
- ground vibration monitoring
- air blast monitoring

Post-blast

- shotrock fragmentation - photo image analysis
- muckpile profiles - throw, heave and swell
- monitoring of load & haul operations
  - bucket load, payload, loading time, haul travel times, tip time, ...
- online vehicle condition monitoring

Crushing and screening

- continuous feed flow
- monitor power consumption and capacities
- continuous weighing
- continuous video image analysis
- metal parts detection

Stockpiles, aggregate quality & dispatching

- laser profiling of stockpiles
- aggregate cubicity
- aggregate micro-fracture density
- weighbridges and billing

Quarry Management

Safety issues of inpit operations

- *pit planning and operations supervision*
- *safety consciousness of workforce*
- *operator hazard training*

=> *minimum occurrence of accidents*

Rollover from terrain bench - 35m drop

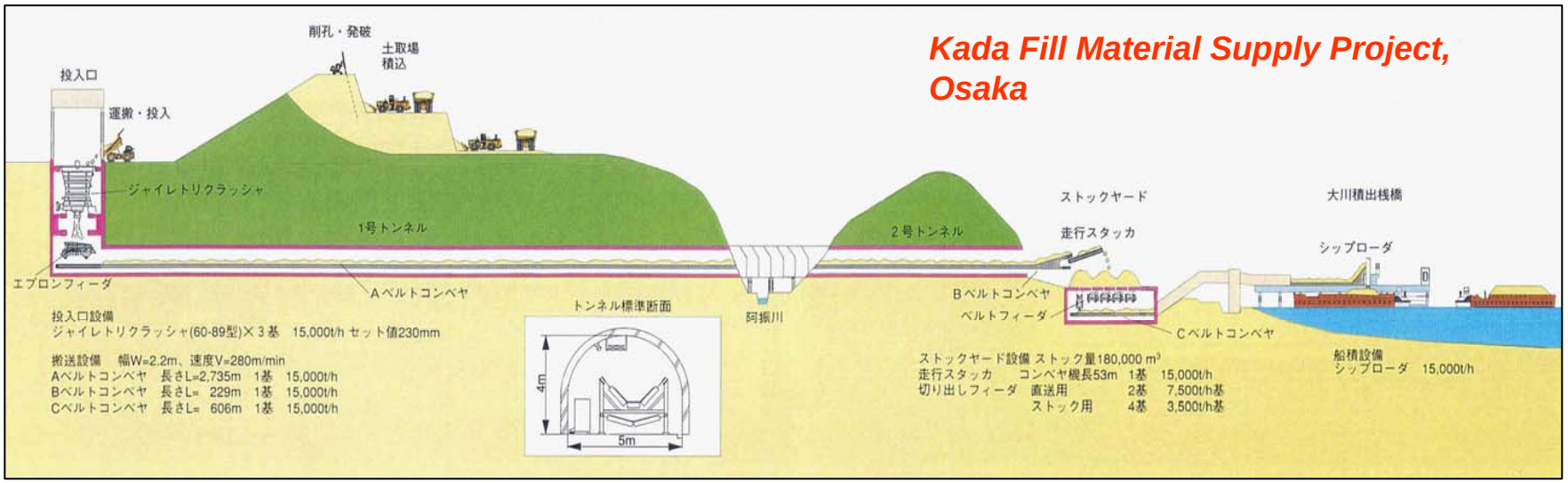
Premature ignition of electric detonators and blast due to lightning

Pit wall failure burying 3 drill rigs in rubble

Quarry Management

Dispatching and transport of aggregates

- ***Medium sized quarries***
  - ***highway truck transport to local markets for distances up to 100 km depending on quality***
- ***Super quarries***
  - ***ship transport to export markets***
  - ***rail or barge transport to metropolitan markets***



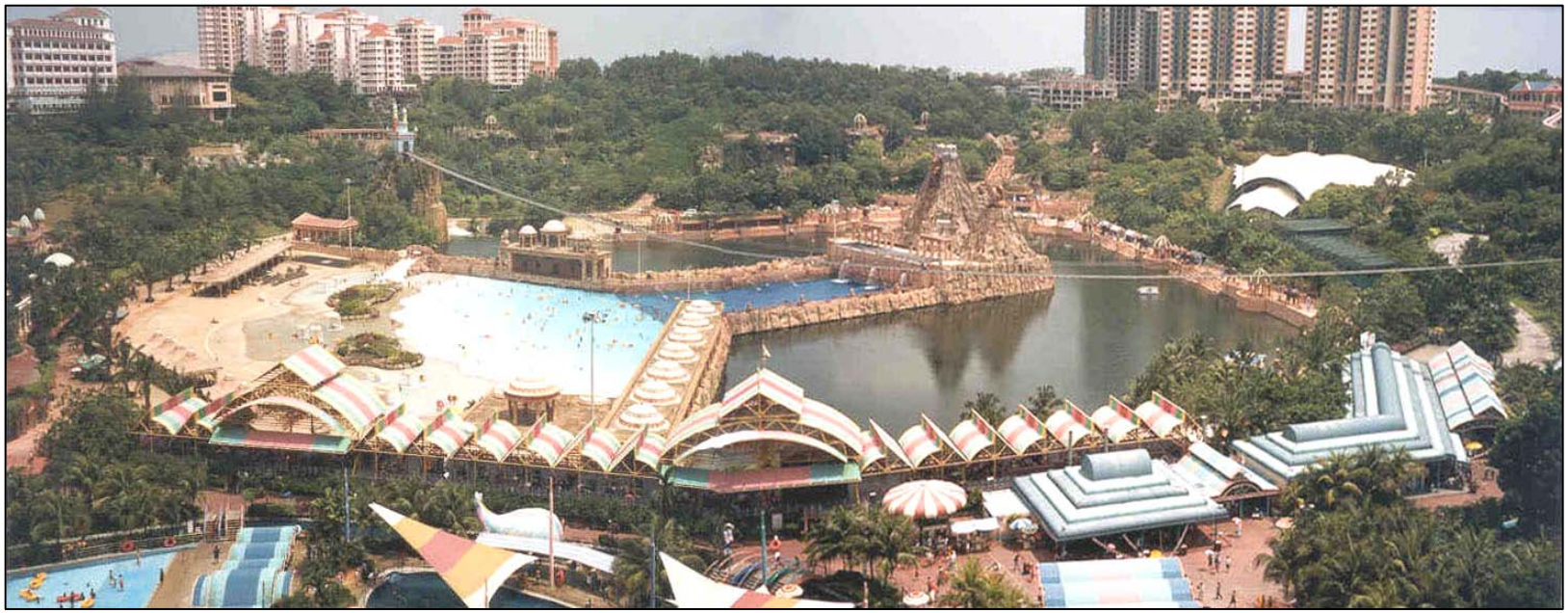
Kada Fill Material Supply Project, Osaka

Quarry Management

Alternative solutions for quarry and pit end-usage

- *housing and industrial development areas*
- *garbage disposal and biogass production*
- *toxic waste disposal*
- *recreational development areas*

Sunway Lagoon Resort, Kuala Lumpur
(previously Sungeiway Tin Mine)



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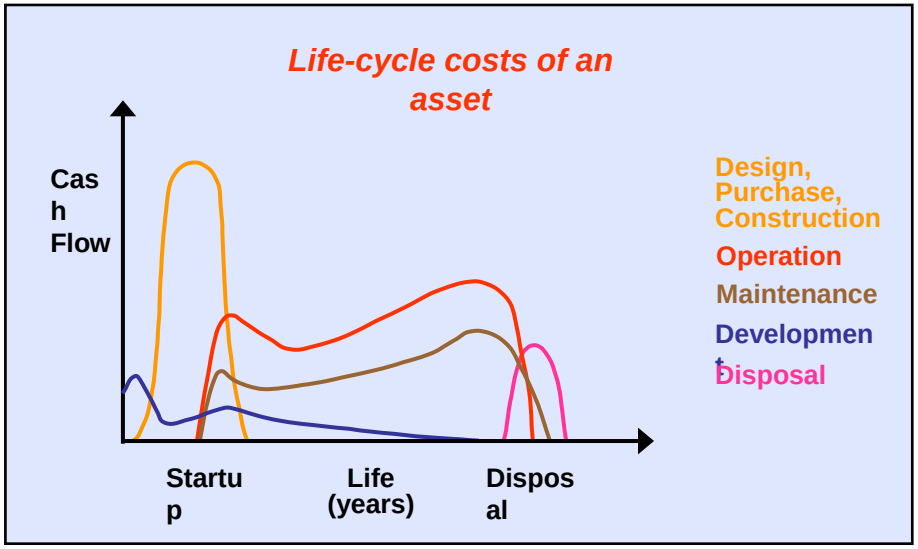
Quarry Management

Long-term fiscal planning and investment evaluation

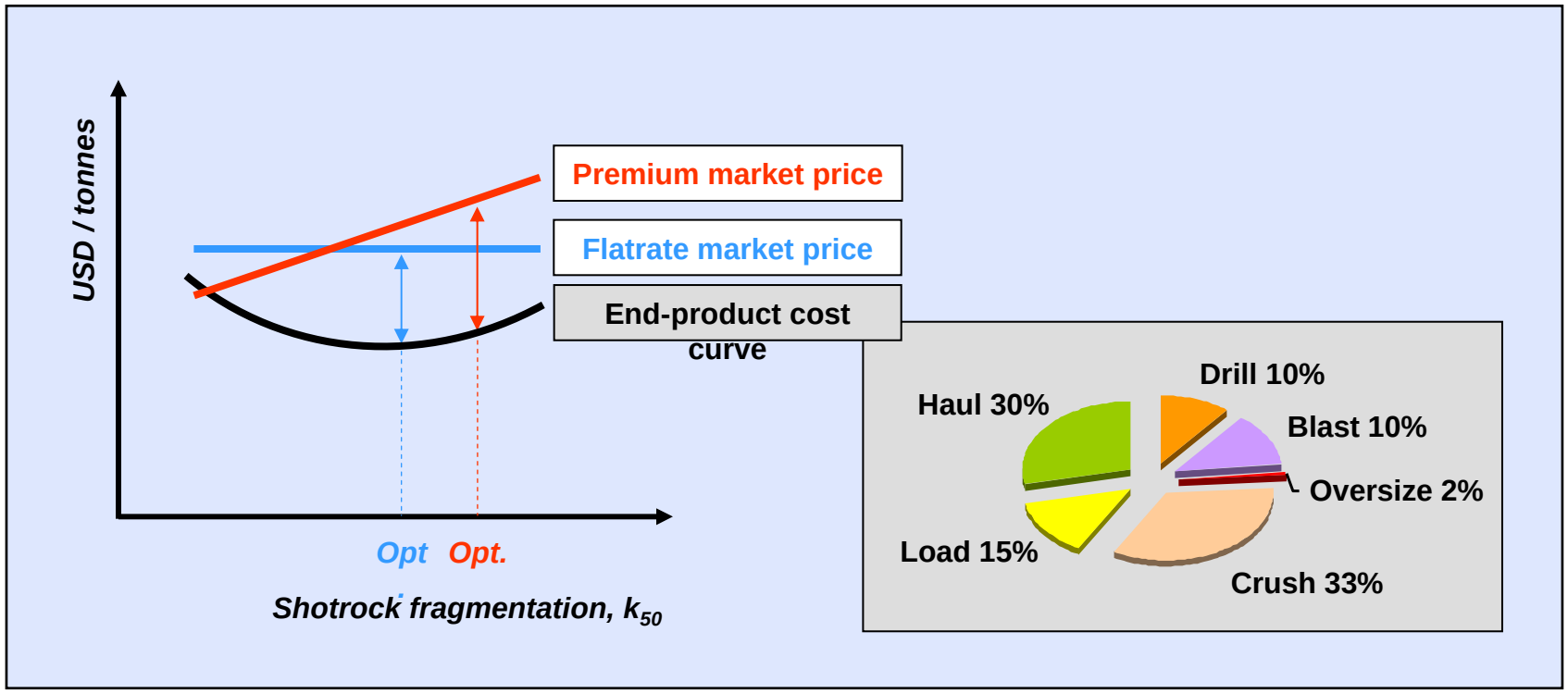
- *local market analysis as to annual saleable volumes and price levels*
- *property assessment*
- *cash-flow analysis and quarry life time costs*
- *investments into pit development and production equipment*
- *especially investments into materials transport equipment vary with quarry and pit layout:*
  - *shaft to stationary primary crusher*
  - *truck transport to stationary primary crusher*
  - *in-pit mobile primary crusher*
  - *conveyor transport to secondary crusher*
- *end-usage of mined out pits*



Quarry Management

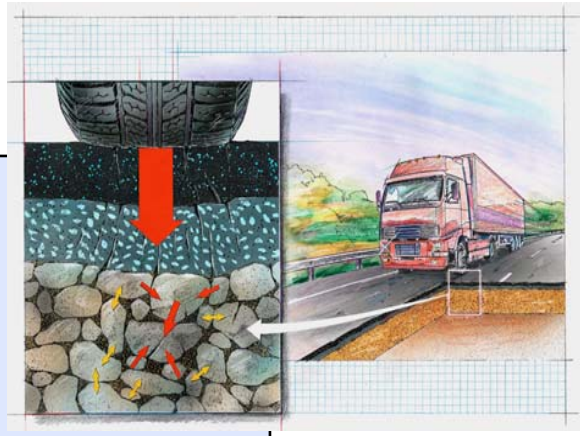
Operational targets for aggregate producers

- *low-cost producer in markets with flatrate end-product pricing*
- *high end-product quality producer in markets with premium end-product pricing*



Quarry Management

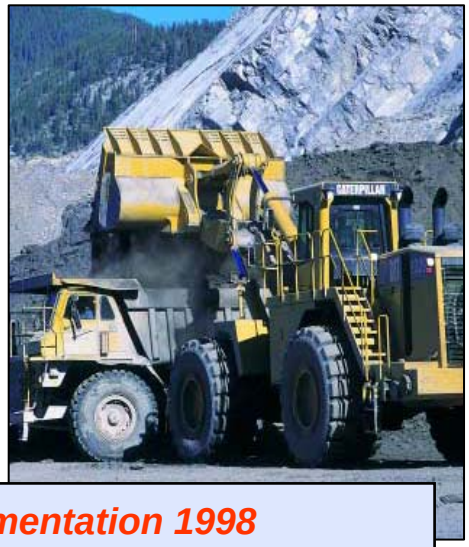
Typical price levels for aggregates



Product	Fraction (mm)	Price $_{VAT}$ (EUR/tonnes)
Wearing course	0 - 16	7.9
Base course	0 - 32	6.7
Road base	0 - 150	5.8
Asphalt	0 - 16	7.9
	5 - 11	10.0
Concrete	8 - 16	9.0
	16 - 32	8.8
Transport		**0.035 EUR / t & km**

Quarry Management

Lafarge Exshaw Cement Quarry



Annual production	*1.6 mill. tonnes*
Rock types	*limestone / dolomite*
Density	*2.6 g/cm^3*
Primary gyratory crusher	*54" / 1370 mm - opening 150 mm*

Base Line 1997

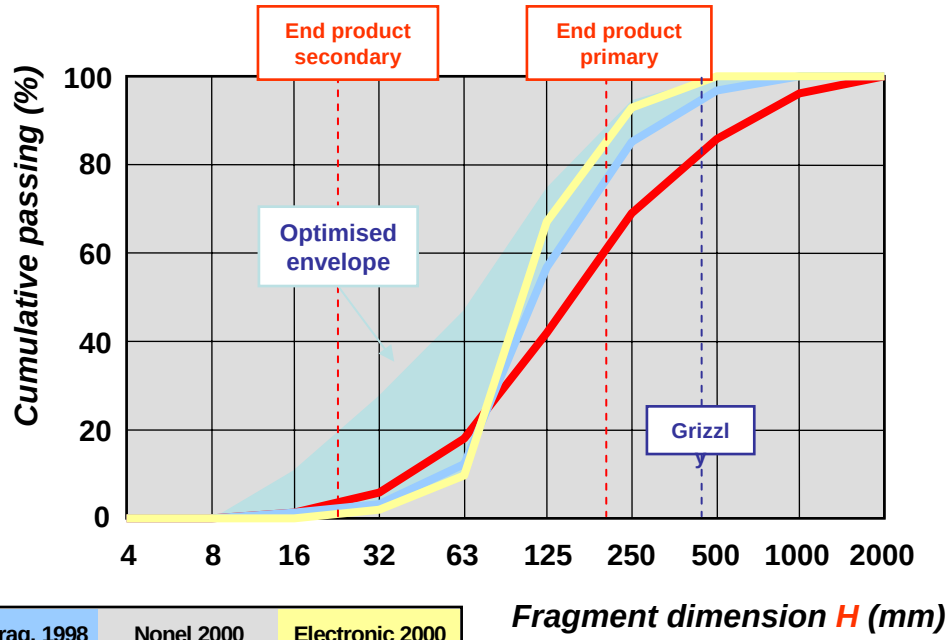
Bench height	*11 m*
Drill-hole diameter	*Ø200 mm*
Drill pattern	*6 x 7 m^2 (rectangular)*
Sub-drill	*1.5 m*
Stemming	*6.0 m (0 - 19 mm matr.)*
Burden delay	*25 ms/m*
Spacing delay	*6.0 ms/m*
Explosive	*ANFO (1.05 g/cm^3)*
Charge per shothole	*215 kg*
Powder factor	*0.47 kg/bm^3*
Back-break	*up to 11 m*
Shotrock fragmentation	*d_{90} = 630 mm*
Secondary crusher	*995 tph*

Finer Fragmentation 1998

Bench height	*11 m*
Drill-hole diameter	*Ø102 mm*
Drill pattern	*3 x 3.5 m^2 (staggered)*
Sub-drill	*1.0 m*
Stemming	*2.0 m (with stem plugs)*
Burden delay	*31 ms/m*
Spacing delay	*7.1 ms/m*
Explosive	*ANFO (0.95 g/cm^3)*
Charge per shothole	*78 kg*
Powder factor	*0.67 kg/bm^3*
Back-break	*avg. 2.9 m*
Shotrock fragmentation	*d_{90} = 300 mm*
Secondary crusher	*1150 tph*
Crushing plant	*30% power reduction*

Quarry Management

Lafarge Exshaw Cont.



		Base Line 1997	Finer Frag. 1998	Nonel 2000	Electronic 2000
Drill & Blast	Shothole diameter, mm	200	102	102	102
	Drill pattern, m2	6 x 7	3 x 3,5	3,5 x 3,5	3,5 x 3,5
	ANFO density, g/cm3	1,05	0,95	1,05	1,05
	Powder factor, kg/bm3	0,47	0,67	0,63	0,63
Firing	Initiation system	NONEL	NONEL	NONEL	Daveytronic
	Downhole delay, ms		500	500	None
	Inter-hole delay, ms	42	25	17	17
	Inter-row delay, ms	150	92	92	92
Shotrock Fragmentation	90% passing - d90, mm	630	300	351	220
	Grizzly retain (> 480 mm), %	18	5	5	0
Ground Vibrations	Distance, m	375	375	280	270
	Peak particle velocity, mm/s	> 8	4,75	6,97	4,51
	Main frequencies, Hz	9 - 21	14 - 21	10 - 21	11 - 39
Plant Production	Peak - 1 hour average, tph	834	980	980	1050
	Power consumption, kW	2259	1808	1979	1858
	Specific energy, kWh/t	2,71	1,84	2,02	1,77
	3 day average, tph	625	725	676	722
	Power consumption, kW	1645	1342	1370	1283
	Specific energy, kWh/t	2,63	1,85	2,03	1,78

Quarry Management

Mt. Coot-tha Quarry, Brisbane

Annual production	*0.4 mill. tonnes*
Rock type	*hornfels with fissure spacing ~ 0.5m*
UCS	*200 MPa*
Density	*2.73 g/cm^3*
Primary jaw crusher	*42" x 48" / 1065 x 1220 mm^2*

Quarry field test program

Bench height	*14 m*
Drill-hole diameter	*Ø102 mm*
Drill pattern	*3.5 x 4.0 m^2 (stagg.)*
Sub-drill	*0.5 m*
Burden delay	*18.6 ms/m*
Spacing delay	*4.3 ms/m*
Explosives	*Watergel (1.2 g/cm^3)*
Charge per shothole	*120 kg*
Powder factor	*0.61 kg/bm^3*
Shotrock fragmentation	*k_{50} ~ 224 mm*
Primary crusher	*300 tonnes/hour*
Oversize (L = 1200mm)	*~ nil*

Current program

Bench height	*14 m*
Drill-hole diameter	*Ø102 mm*
Drill pattern	*3.8 x 4.3 m^2 (staggered)*
Sub-drill	*0.5 m*
Burden delay	*17.1 ms/m*
Spacing delay	*5.8 ms/m*
Explosives	*Watergel (1.2 g/cm^3)*
Charge per shothole	*120 kg*
Powder factor	*0.52 kg/bm^3*
Shotrock fragmentation	*k_{50} ~ 269 mm*
Primary crusher	*280 tonnes/hour*
Oversize (L = 1200 mm)	*5 - 7 %*